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EARLY LIFE OF E. E. BARNARD.*

S. W. BURNHAM.

Edward Emerson Barnard was born in Nashville, Tennessee, December 16, 1857. His early education was limited to two months' attendance at a common school, and such instruction as his excellent mother could give him at home; and all of his acquirements in literature, the sciences and languages in late years are the results of his own earnest efforts. Fatherless and destitute at the close of the war, he began at the age of eight or nine to work in a large photographic studio in Nashville, and continued to follow the occupation of photographer until 1883. During this time he had mastered every department of the photographic art, and had become invaluable to his employers as a faithful and accomplished assistant. His has been a struggle single-handed for existence. Handicapped by sorest distress and poverty from the first, he has fought the battle of life alone and is in the supremest sense of the word a self-made man, as can be well attested by the people of his native city.

From an early age he had been interested in optical matters, and this interest was increased by the use of the various lenses employed in the gallery. He was always interested in watching the heavens at night, the change of the face of the sky from month to month, the movements of the planets, the phenomena of eclipses, and other striking astronomical events. This interest received an impulse in a curious way. In 1876 a friend happened to leave in the young photographer's possession for a few days an old book which he was delighted to find was a copy of Dr. Thomas Dick's Practical Astronomer. This book was studied with great avidity, and it awakened a thirst for astronomical knowledge which has never since ceased to be controlling. This work, long since left behind in the great advance of the science was like a revelation. It told the stories of the stars and the planets, and the wonders revealed by the telescope. Now, for the first time, he had some idea of the uses of astronomical instru-

* This is the first of a series of articles portions of which have already appeared in *Harper's Magazine*, August, 1893.

ments. He had never seen either a telescope or an Observatory. All he knew of the literature of the subject was found in this old book. In its day it was one of the most valuable general works on the subject, and it is still a delightful book to read; but modern observers, aided by improvements in methods and instrumental appliances, have made many discoveries since that time, and a treatise on the new astronomy of the nineteenth century must bear a recent date. From the maps of the constellations and other engravings, he speedily learned to identify the objects in the sky about which he had been reading; and the descriptions of celestial wonders had now a new interest. Then came the desire to possess some kind of telescope, and finally he obtained the object lens of a common spy-glass, and mounted it in a paper tube made by himself. This lens was about one inch in diameter and, of course, was never intended for looking at celestial objects. Still it revealed the heavens as they can never be seen by the unaided eye, and showed the beautiful crescent form of Venus and the discs of Jupiter and other planets. It is certain that the intense excitement caused by the views obtained by this crude instrument was never equalled in after years when he was occupied in making a series of brilliant discoveries with the largest and most powerful telescope in the world. Such excitement comes but once in a lifetime, although the enthusiasm and interest in the subject may never be abated.

About this time a traveling showman with a small glass for street exhibition appeared in Nashville, and young Barnard was a steady patron whenever nickels were sufficiently plenty to warrant such a dissipation. This was not much of a telescope, but it was superior to the home-made affair he had constructed for himself. He resolved to have a better instrument of his own, and after practicing the most rigid economy, he was enabled in 1877 to purchase a telescope of five inches aperture with a proper mounting, and a suitable equipment of eye-pieces and other accessories. In August of that year he met in Nashville Professor Simon Newcomb, the distinguished Washington astronomer and received from him advice and kindly suggestion in regard to the future; and this encouragement was of much value in his efforts to accomplish something with the new instrument. In these days of expensive equatorials mounted in revolving domes with every mechanical and optical appliance of the most perfect description, a portable instrument to be used on the house top, in the back yard, or wherever it was most convenient, would hardly be thought worthy of mention, but still it was an

instrument with which the young astronomer, with a zeal and enthusiasm superior to all outside discouragements, could do valuable astronomical work and this may be said to be the beginning of an unbroken series of brilliant discoveries and observations of permanent value in a wide range of practical astronomical subjects.

His first systematic work of any importance with this telescope was a careful study of the planet Jupiter, and the popular scientific periodicals of the time contain many of his contributions on this subject. This planet, the largest of the solar system, seems to have had a special charm for the young astronomer at the very beginning of his use of the telescope; and, to use his own modest statement at the time, he "began regular observations of Jupiter and contributed his mite in drawings and observations of that changing old planet." In late years this work was continued with instruments of much greater power, and finally culminated, as will be referred to hereafter, in the grand discovery of a new member of the magnificent Jovian system. It may be worth mentioning in this connection that when he first went to work in the photographic gallery he was placed on a large platform in charge of the printing with an immense solar camera on the roof of the gallery. This was the largest camera of the kind in existence in this country or elsewhere, and was designed to print directly life-sized figures on silvered paper. It was his duty to keep the camera accurately directed to the Sun, the sunlight being passed through the mammoth condensers and the negative thus projecting the image on the sensitized paper. This colossal instrument bore its name significant now, in large letters, painted on its side, "*Jupiter.*"

THE FIXED STARS.

W. H. S. MONCK, DUBLIN, IRELAND.

I.

Probably the greatest advance that astronomy has made within the present century has been in Stellar Astronomy—the department of the fixed stars and the nebulæ that belong to the same remote region. And it is in this department also that astronomy is at present advancing with the most rapid strides—so much so that any treatise on Stellar Astronomy, unless frequently rewritten would soon be out of date. A periodical like POPULAR

ASTRONOMY has the advantage of being able, not only to give a sketch of the state of the science at the existing juncture, but to note its advances from time to time.

The history of Stellar Astronomy is interesting, but until recently it did not form a science. Star catalogues may form the basis of a science, but they are not scientific in themselves. The discovery implied in the very title of Fixed Stars is no doubt of early date; but it was reserved for the moderns to ascertain that they are not fixed and to determine within certain limits the velocity and direction of their motions. But before the great discovery which is associated with the name of Copernicus the fixity of these stars was calculated rather to mislead astronomers than to direct them to the truth. How could a number of stars, situated at various distances, but measured in all cases by thousands of millions of miles, perform a revolution round the Earth in every twenty-four hours? The velocity supposed by such a theory was inconceivable, and the natural supposition was that they were situated pretty nearly at the same distance from us and that not a very great one. And without forming some tolerable notion of their distances it was impossible to arrive at any trustworthy conclusion with respect to their nature. If comparatively near us their light must fall greatly short of that of the Sun, and if sun-like bodies they must be either much smaller or much fainter than the luminary of our system. The Copernican theory had to win its laurels before any real progress could be made. When that theory was once established, it was natural to suppose that the apparent motionlessness of the fixed stars arose from their distances being vastly greater than those of the Sun or planets. That bodies situated at such vast distances should shine as brightly as they do by reflected sunlight seemed improbable. They gave light of their own. They were suns; though whether they were not much smaller suns than ours remained still undecided. The Copernican theory too was speedily followed by the discovery that the Sun was more remote than had hitherto been supposed, and of course the distances of the fixed stars were proportionally augmented.

It was soon found that the only way of endeavoring to ascertain the distance of a fixed star was by means of its annual parallax or the angle which the radius of the Earth's orbit subtended at the star. Hooke appears to have been the first to make this attempt. He obtained for the star γ Draconis an annual parallax of nearly half a minute. This was of course altogether wide of the mark, but still it made the star about

7,000 times as distant as the Sun, at which distance the Sun's light would be reduced in the proportion of 50,000,000 to 1. The sun-like character of the star was thus confirmed. But even if astronomical instruments had then been much more perfect than they were at this period, no satisfactory result could have been attained. It was not until after Bradley's discovery of the aberration of light that the problem of ascertaining the distance of a fixed star could be taken up with any real prospect of success. The result of repeated trials was that the parallax rarely exceeded the limits of error, and that even where it did so the limits of error usually bore a considerable proportion to the result. It may, I think, be laid down that no star hitherto examined (and most of those likely to have sensible parallaxes have been examined) has a parallax of as much as one second or is situated nearer to us than 200,000 times the distance of the Sun. The Sun's light would be reduced in the proportion of 40,000,000,000 to 1 if it were removed to this distance; and though it is no easy task to compare the light of the Sun with that of a star, I think most readers will be prepared to admit that 40,000,000,000 stars as bright as Sirius would give more light than the Sun.

The telescope had not been long in use before some double stars were discovered and the hypothesis that one of these stars revolved round the other as the planets revolve round the Sun was not an unnatural one to form. It was reserved for Sir William Herschel however to discover that such was the fact, and the discovery I believe belongs to the present century. Besides the difficulty of measuring distances and angles with the requisite accuracy, however, another difficulty presented itself in our efforts to extend the law of gravitation to the fixed stars. The smaller star ought under the influence of that law to describe an ellipse having the larger star in the focus But if an ellipse is presented sideways to the eye—as the orbit of a double star usually will be—it will indeed still appear to be an ellipse but the focus will generally be displaced. The usual result therefore is that one star will revolve round the other in an ellipse, but the larger star will not appear to be in the focus. We can find, however, at what angle the plane of the orbit should be inclined to the line of sight so as to make the larger star the focus of the real ellipse; and in this way the orbits of about seventy double stars have been already computed. But that these stars are moving under the influence of gravitation is assumed, not proved. To prove it we should be able to show that the orbit is

really inclined to the line of sight at the supposed angle. The spectroscope may clear up this doubt hereafter by ascertaining the velocity of the smaller star in the line of sight at different points of its orbit. But that instrument has to a large extent removed the doubt already. It has proved that the atmospheres of the stars contain elements such as hydrogen and iron which are known to gravitate. If these elements gravitate when within the limits of the solar system few persons will suppose that they lose their attraction when they pass beyond those limits—that, for instance ,the carbon in a comet which moves in a parabolic or hyperbolic orbit loses its attractive force when it gets to a sufficient distance from the Sun, or else that it continues to attract and to be attracted by the Sun, though it is uninfluenced by the carbon of the other stars which it approaches in its grand sweep though the sky.

That the fixed stars are gravitating bodies shining by their own inherent light and comparable with the Sun both as regards mass and brilliancy seems thus to be established. Yet probably an astronomer who made this assertion in the last year of the eighteenth century would have gone somewhat beyond the evidence then available. And as there are very few stars whose parallaxes can as yet be regarded as reliable there are also very few binary stars whose orbits can be regarded as certain. But these uncertainties do not affect our general results. In the first place we know that the error cannot exceed limits which in some cases are rather moderate. In the second place when we are dealing not with individual stars but with classes of stars the averages are much more reliable than any single result. And the average parallaxes or distances of the stars are confirmed in other ways. As soon as it was conjectured that the stars were subject to the law of gravitation it was inferred that they were not motionless. Comparison of different catalogues compiled at different times have established the fact that many of them move, and have enabled us to determine the amount of the motion measured on the celestial sphere. Since the introduction of the spectroscope we have obtained another measure of velocity —velocity in the line of sight. The former velocity, however, is measured in arcs on the celestial sphere—the latter in miles per second. As the stars are too distant to be much influenced by the motions of the solar system we may fairly assume that, on a general average, the motion in any given direction will be about equal to that in another direction at right angles to it; and in this way we can estimate what motion in miles per second

is equivalent to a given motion in seconds or fractions of a second on the celestial arc. The result is to confirm the great distances of the fixed stars. The average motion of about fifty stars in the line of sight, according to Vogel's observations, is a little over 10 miles per second. Stars of this brightness have a motion (on the average) on the celestial vault of less than half a second annually; and this embraces the motions in two out of three directions mutually at right angles where the motion in the line of sight gives the third. Very small parallaxes or very great distances are thus indicated. But my present object is rather to point out that all the stars are in motion as they would be if under the influence of gravitation. Indeed in some cases the motion seems to be too great to be accounted for by gravitation alone; but Newton had to combine an original projectile force with gravitation in order to explain the motions of the planets; and the attempt to get over this difficulty by means of the nebular hypothesis has not proved as successful in the case of the comets as of the planets. Now there is every reason to believe that an original projectile force combined with gravitation will explain all the motions of the fixed stars and that the law of gravitation thus extends to the utmost limits of the universe.

The principles that the fixed stars are similar to the Sun not to the planets in their self luminosity, in the intensity of their light, and in their masses, and that they are gravitating bodies moving through space with great velocity, may be said to form the foundation of stellar astronomy. These stars are connected with us in two ways which our descendants may yet resolve into one —by the universal gravitation, and by the ether whose undulations convey their light to us, and which must therefore occupy the whole of the intervening space. This ether apparently does not gravitate, but it may notwithstanding be the medium by which the influence of gravitation, as well as of heat, light and electricity, is propagated.

One fact which deterred the earlier astronomers from accepting the enormous distances of the fixed stars to which modern research leads us was the discs which these stars present in the telescope. But these discs are no doubt spurious, arising from the defects of our telescopes as optical instruments. When we use higher magnifying powers they do not increase proportionally as those of the planets do; and when the dark edge of the Moon passes over a fixed star it is usually occulted instantaneously instead of being gradually extinguished as would be the case if it represented a really sensible disc. The few exceptions to this rule

probably arise either from the existence of a faint lunar atmosphere, or from the star being a close double star. Stars which must present towards us surfaces of vast extent—in many cases probably larger than that of the Sun—are so distant that any measure of their real discs is unattainable. Probably in no case does the true diameter of a fixed star as seen from the Earth amount to the thousandth part of a second! Yet everyone knows how brilliant some of them look in our midnight sky. We need not be surprised to learn that in point of brilliancy many of them rank higher than the Sun himself. But our reasons for arriving at this latter conclusion must be deferred for another article.

THE SPECTROSCOPE AND SOME OF ITS APPLICATIONS.

JAMES E. KEELER.

III. *Practical Details Relating to the Adjustment and Use of the Instrument.*

We now turn to a consideration of the conditions on which the efficiency of the spectroscope depends. It is desirable that the spectrum shall be bright, for we are seldom troubled with too much light, and that the lines shall be fine and sharp, or in other words that the spectrum shall be pure. These are directly conflicting requirements, for the brightness of the spectrum is increased by widening the slit (unless it consists of isolated bright lines), and the purity is increased by narrowing it. Hence in practice a compromise is adopted, determined in each case by direct experiment. By using a higher magnifying power on the telescope we can increase the apparent size of the spectrum, but as the lines are magnified, at the same time the purity is not changed and the spectrum is dimmed. In fact the laws which apply to the telescope when used to examine the spectrum are the same as when it is used for any other purpose.

When the dimensions of other parts of the instrument are altered the effect is not quite so simple. It should be observed that the different parts should be adapted to one another in a well constructed instrument, so that no light may be wasted, and at the same time no unnecessary material may be employed. Thus, the prism should evidently be large enough to transmit the full cylindrical beam of light from the collimator, and it would be a waste of material to make it larger. For the same reason the

telescope objective should be of the same size as the collimator lens. Assuming that these principles of construction are observed, we may call the diameter of the collimator lens the *aperture* of the spectroscope.

It is an important proposition that the brightness of the spectrum is proportional to the square of the aperture of the spectroscope. Without attempting to demonstrate the proposition I will give some examples to illustrate its truth. Suppose that the collimator has a focal length of twelve inches, and an aperture of one inch, and that the observer has adjusted the width of the slit until the brightness and purity of the spectrum are satisfactory. Now let the slit with its width unchanged be placed in a collimator of six inches focal length, and half an inch aperture, and the new collimator be screwed into the place of the old one. It might seem at first sight as if the brightness would be the same, for the new lens catches all the light that fell upon the old one; but with the new collimator each monochromatic image of the slit is twice as long and twice as wide as before, while the length of the spectrum is unchanged; hence the purity of the spectrum has suffered, and if the slit is narrowed until the original purity is restored, the brightness will be reduced to one-fourth of its original value.

The same thing may perhaps be seen more clearly by imagining the collimator lens to be increased in size, the focal length remaining the same. Starting with the original conditions, if the aperture of the collimator is made two inches, the prism and telescope objective being increased in proportion, the purity will not be changed, for the slit-width remains the same, and the focal length of the collimator remains the same, but the new lens receives four times as much light as the old one, and the spectrum will be four times brighter.

Hence in estimating the efficiency of a spectroscope with regard to brightness of the spectrum, the aperture is to be considered as the essential feature. The focal lengths of the telescopes have no bearing on the subject, and may be anything that is convenient.

The *resolving power* of a spectroscope expresses its power of dividing close double lines in the spectrum. With the same aperture it may be increased by increasing the dispersion, either by adding more prisms or by using more highly dispersive material, for the lines in the spectrum are thereby more widely separated without being widened themselves; or the dispersion remaining constant, it may be increased by using a larger aperture, which gives finer and sharper images for the lines, just as increasing the aperture of a telescope diminishes the size of star-discs and allows

closer double stars to be separated. It has been shown that with simple prisms of the same material, the resolving power is directly proportional to the difference between the longest and shortest paths of the light in traversing the prisms; that is, if the prisms are properly proportioned, to the sum of their bases. Hence one large prism may be equal in resolving power to several small ones.

If we take as unity that resolving power which allows the separation of two lines differing by the thousandth part of their own wave-length* (which is very nearly the resolving power required to separate the D lines) we may express the resolving power of a spectroscope numerically. Thus, to separate the D lines requires a heavy flint glass prism with a base of about four-tenths of an inch; a prism of the same glass with a base of two inches would therefore have a resolving power of five. The resolving power of a prism is greater in the upper part of the spectrum than in the lower.

With compound prisms the crown glass must first be reduced to its equivalent in flint glass, allowing for the greater dispersive power of the latter, before applying the rule; the exact relation depends upon the kinds of glass used, but roughly, we may take one inch of flint glass as equivalent to two of crown.

The inferiority of the direct-vision prism in respect to resolving power can now be correctly appreciated. To take a real example, I have a large direct-vision prism made of five prisms, three of crown and two of flint glass arranged in the manner already described. On one side are the bases of the flint glass prisms, measuring together four inches; on the other side are the three bases of crown glass, with a total length of six inches. Taking the six inches of crown glass as equivalent to three of flint, there is a difference of one inch of flint glass between the opposite sides, so that the whole combination is only equivalent in resolving power to a simple flint glass prism with a base of one inch, and is decidedly its inferior in brightness.

In my first article I referred to the advantage of knowing how to change the dispersion of a prism by displacing it slightly from the position of minimum deviation, and we are now prepared to understand the exact nature of the change. As the thickness of glass traversed by the rays of light is very little affected by a slight displacement of the prism, the resolving power remains the same, and we have a change of dispersion unaccompanied by a change of purity. When the dispersion is increased by rotating

* Professor Schuster's definition.

the prism, the lines in the spectrum are broadened, as if the original spectrum had been viewed with a higher magnifying power; but with this important difference,—that whereas in the latter case the width of the spectrum would apparently be increased, in the former it remains unchanged. Rotation of the prism produces in fact a *horizontal* magnification of the spectrum, which with respect to brightness is more advantageous than enlargement with an eyepiece. Sir David Brewster made a telescope by combining two crossed achromatic prisms, which those who are curious about the matter will find described in his Treatise on Optics.

Hitherto we have supposed that the light coming through the slit diverges sufficiently to cover the whole of the collimator lens, as it always will do if the source of light is a flame close to the slit, but in practice cases will arise when the whole lens is not covered. When we point the colimator directly at the Sun, the rays from opposite limbs pass through the slit in straight lines and diverge at an angle of about half a degree, (the Sun's angular diameter), so that the spot of light on the collimator covers only half a degree as seen from the slit. With a collimator ten inches long the illuminated part of the lens is less than a tenth of an inch in diameter,* and all the rest of it might as well be covered up, for the light from the sky around the Sun is too faint to need consideration. Most of the optical power of the instrument is wasted.

In this case the *effective* aperture of the spectroscope is about a tenth of an inch. The observer, in order to get the benefit of the full power of his instrument, must see that the effective aperture is as great as the real aperture, that is, that the collimator lens is filled with light. Some small instruments exhibited at Chicago were intended to point directly to the Sun, as they were equatorially mounted and carefully balanced, but the necessity of observing the above condition had been overlooked.

In order to utilize the whole aperture when the collimator is directed to the Sun, we may place a lens in front of the slit, so as to form an image of the Sun on the slit-plate. The angular aperture of the lens must at least equal that of the collimator lens, that is, they must both subtend the same angle as seen from the slit, otherwise the collimator lens will not be completely illuminated. The brightness of the spectrum is then independent of the

* As the slit has considerable length, the illuminated part of the collimator is really a band half a degree wide, but the resolving power is the same as if the slit were indefinitely short.

size of the image lens, a large lens giving no greater brightness than a small one. In astronomical observations the image lens is the object-glass of the telescope to which the spectroscope is attached.

Although the brightness of the spectrum is independent of the dimensions of the image lens, the breadth of the spectrum is not. The greater the focal length of the lens, the larger will be the image of the Sun on the slit plate. If the diameter of the Sun's image is a quarter of an inch, each monochromatic image of the slit will be a quarter of an inch long, and hence the spectrum will be a quarter of an inch wide, for the open parts of the slit not covered by the solar image are too feebly illuminated to give a spectrum of appreciable brightness. Practically, therefore, the focus of the image lens should not be too short, say not less than twelve or fourteen inches.

A new advantage gained by the use of the image lens is the power it gives of observing the spectrum of each individual part of the source of light. Thus, if a sunspot on the solar image is brought within the jaws of the slit, its spectrum will appear in the eyepiece. Of course the solar image would have to be pretty large to give a spot-spectrum broad enough for observation. A spectroscope provided with an image lens is sometimes called an analyzing spectroscope. In the laboratory the image lens is useful when the source of light is very small, an electric spark, for instance, or when there would be danger of burning the slit by bringing it too close to a flame.

For measuring the positions of lines in the spectrum various devices are used. Fixed cross-wires in the eyepiece may be brought into coincidence with the lines, and the positions of the telescope read off on a graduated circle, or for short intervals a micrometer eyepiece may be used. A common method is to place a finely divided scale, usually obtained by photography, in such a position that it will be reflected from the surface of the prism next to the telescope and appear in contact with the spectrum seen in the eyepiece. The scale must be in the principal focus of a collimating lens, in order that the rays striking the reflecting surface may be parallel. The small spectroscopes used in chemical laboratories are usually furnished with this device.

For small instruments probably the most accurate method of determining the position of a line is by direct comparison with the solar spectrum or with other well-known lines. For this purpose a small reflecting prism called a comparison prism is placed over part of a slit, and the spectra of the two sources of

light can be seen together, one formed by rays entering the slit directly, and the other by rays reflected into it by the comparison prism. It is then quite easy to determine the place of an unknown line among the lines of the solar spectrum, and hence its wave-length.

The practical matters to which I have devoted this article are those which should most carefully be borne in mind by the observer. They are not absolutely necessary to a good understanding of the results which the spectroscope has accomplished, but they are of importance in actual spectroscopic work. The spectrum of a body is seldom obtained by pointing a spectroscope at it in an off-hand manner, and as some of my readers are themselves supposed to be using small instruments, and hence to be interested in knowing how results are obtained, as well as what the results are, I hope these details about instruments and methods may not be amiss.

THE HEAVENLY BODIES.

DANIEL KIRKWOOD.

In the variety of their magnitudes and motions the heavenly bodies present an indefinite series for study and description. The great and small are there. Of the former we may name our system's source of light, surpassing in volume more than a million times the world which we inhabit, and whose scenery has occupied the attention of a thousand generations. Our initial number opened with a brief detail of facts. The small planets revealed became still more minute as discovery advanced, till some were found whose diameters were not greater than ten or twelve miles. But among the satellite rings, whose magnitudes are indefinitely minute we soon weary in the contemplation. Leaving in imagination our native system, we find in telescopic revelations, suns surpassing in magnitude and splendor the orb of day itself. Let us study, in brief, some of the creations thus revealed.

I.

Sirius and its Companion.

In beauty and grandeur what scenery can surpass the winter's midnight sky? In view of its splendors who has not asked, which is the greatest of these distant orbs? Is it stationary or in motion? If moving is it approaching the Earth, or receding from it,

and at what rate? Which radiates the greatest quantity of light, and what is its amount compared with that of the Sun? In what system is found the largest satellite or companion star? Some of these questions, within the memory of persons still living, were thought to transcend man's loftiest efforts. The story of their solution forms one of the most brilliant chapters in the records of human progress.

Of the numerous efforts to find the annual parallax of Sirius, perhaps none is entitled to greater confidence than that of Maclear, or Abbe's rediscussion of Maclear's results in the *Monthly Notices of the Royal Astronomical Society*, Vol. XXVIII, p. 6. This value is twenty-seven one hundredths of a second of arc, corresponding to the distance 761,704 times that of the sun from the earth, or seventy-one millions of millions of miles. Light, moving at the rate of 186,000 miles in a second, is more than twelve years in passing from Sirius to the Earth.

The proper motion of this star has been known since the time of Halley. Within the last sixty years, however, irregularities have been observed, such as might result from the disturbing action of a neighboring star. These anomalies, detected by different astronomers, suggested the theory of an undiscovered satellite. In 1862 this predicted companion was brought to light by Alvan G. Clark, Esq., of Cambridgeport, Mass. Since that date, therefore, Sirius and its disturbing attendant have been known and observed as a binary system.

Mass and Elements of the Binary.

The apparent semi-axis of the companion's orbit is 8″.53; hence with the adopted parallax the real semi-axis, in astronomical units, is 31.6 In other words, the mean distance of the satellite from the centre of Sirius is 2,939,000,000 miles—slightly greater than the distance of Neptune from the sun. With the calculated eccentricity—0.591—the least distance apart is found to be 13 astronomical units, or, 1,209,000,000 miles. The mass of Sirius is twice that of the companion, and at least fourteen times that of the sun. Other values of the parallax make the mass still greater.

Light—Volume—Density.

The intrinsic light of Sirius is 83 times that of the sun. Assuming, then, that their surfaces have equal luminosity, the diameter of Sirius is 9.1 times that of the Sun, or, 7,826,000 miles. The volume is 755 times greater than the Sun's and as the mass is but

14 times greater, the mean density is 0.018, that of the Sun being unity.

The study of this wonderful system has led to remarkable results. While the mass of Sirius is only twice that of the satellite, its light is twelve thousand times greater. Can this difference be due to the more rapid cooling of the lesser body? If so, as the mass of the star is seven times greater than that of the Sun, the age of the binary must be vastly greater than that of the solar system. If, Sirius, therefore, is the centre of a multiple cluster, any smaller members may have advanced so far in the process of cooling as to have lost entirely their native light—a condition to which the satellite discovered by Clark may be gradually approaching.

Dr. Huggins, of London, though not the first to suggest the use of the spectroscope in determining the motion of stars in the line of sight, was the first to reduce the suggestion to practice. His results are well known to astronomers. In the case of Sirius, as might have been expected of a body moving under the influence of a disturbing cause, the rate has been variable. Without entering into details, it may be remarked that very careful measurements have indicated a recession of from twenty to twenty-five miles per second.

The mass of a binary star can be determined only when its distance is known. These distances have not been found except for about thirty stars. The question, therefore, what star has the greatest quantity of matter, can receive no definite answer except in regard to those of known parallax. So far as measured, Sirius has undoubtedly the greatest mass as well as the greatest brightness, intrinsic and apparent. Its companion, moreover, is the largest satellite yet recognized.

Origin of the Binary.

The relations of this satellite to Sirius suggest a modification of the nebular hypothesis. The least distance between the two members is 13 millions of miles; the greatest, 50 millions. At the former, the apparent diameter of Sirius as seen from the *comes* is about 22′; at the latter 5′ 30″. This cometary eccentricity, as well as that of many other binaries, could hardly have originated in circular rings. It seems rather to indicate the primitive formation of two distinct nuclei in the same nebula. According to Laplace the planets of the solar system had their origin in circular rings abandoned at the Sun's equator.

SHOOTING STARS.

How to Observe Them and What They Teach Us.

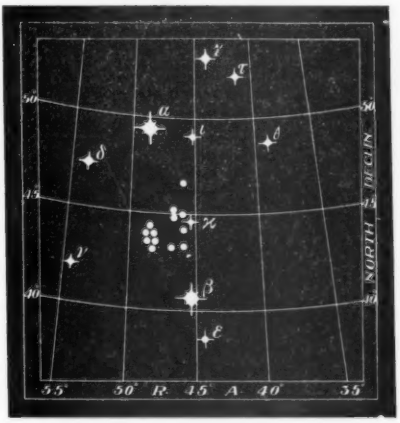
W. F. DENNING, BRISTOL, ENGLAND.

V.—RADIATION AND DURATION OF METEOR SHOWERS.

The radiation of meteors is far from being precisely uniform in character, for different systems appear to exhibit peculiarities of distinct type. While some radiants are diffused over areas of 3, 5, or 7 degrees others are so limited that they may justly be termed *points*. We have already referred to the Andromedes of Biela's comet as supplying a very pronounced instance of indefinite radiation. The precise cause of this has not perhaps been settled but Professor Newton believes the explanation is to be found in "the glancing of meteors on entering the air. The meteoroid is probably a fragmentary body of irregular form and the burning off of the solid fragments as soon as burning begins makes them move in straight lines thereafter. The curvature of path otherwise should continue through the whole length of the luminous tracks. This glancing is not confined to the Biela meteors, it was true of the Leonids and still more so of the Perseids. It is reasonable to assume that it is true of all shooting stars." Many will be disposed to accept his ingenious explanation, but the writer would note that the radiants of the Leonids and Perseids are far more sharply defined than that of the Andromedes. It is extremely probable that the scattered radiation often ascribed to the former showers is an apparent effect only, brought about by including the meteors from closely neighboring systems and by errors in recording the path directions of the various meteors observed. At Bristol the radiants of the Leonids and Perseids have been frequently seen as very exact and restricted centers presenting a wide distinction to the diffuse radiation of the Andromedes.

As to "duration of activity" this is another feature in reference to which future observation will furnish important evidence. We know that the Perseids maintain a continuous fall during more than a month, and that the Orionids are to be seen for about three weeks, while the Quadraulids, Lyrids, Leonids and Andromedes are each probably confined to a week's activity. Some other showers seem to be exceedingly fugitive, appearing only on a single night. But it must be acknowledged that with

regard to the mass of feeble systems, the question as to their visible duration remains an open one. The difficulty of obtaining observations on many consecutive nights and of following up the work year by year, the frequent hindrances occasioned by moonlight, clouds and other causes, have prevented our gaining anything but a vague idea as to the operations of the really tenuous streams. Many of them apparently show a stationary radiant and a fitful activity during extended periods, but the cause remains an unsolved enigma. How shall we deal, for instance, with a shower which recurs again and again from a position between the stars α and β Persei and of which the following observations have been made at Bristol in the months of July, August and September:



Date.	Radiant.	Date.	Radiant.
	° °		° °
1877 July 20	...47 + 45	1879 Aug. 21-23	...46 + 47*
1884 July 23-25	...48 + 43	1887 Aug. 30	...46 + 43
1886 Aug. 2-10	...48 + 43	1887 Sept. 12-24	...47 + 43
1888 Aug. 5-14	...48 + 44	1885 Sept. 15	...48 + 43
1877 Aug. 3-16	...46 + 45	1877 Sept. 15-16	...47 + 45
1893 Aug. 8-16	...48 + 44	1886 Sept. 22-30	...48 + 44
1884 Aug. 19-21	...46 + 44		

Do these various positions represent a number of different showers emanating curiously enough, from virtually the same place in the firmament, and are we in fact to consider the coincidences of radiation as purely accidental? Or, on the other hand,

* The position of this radiant was estimated from paths not registered and it is evidently 3° N. of the correct place.

are we justified in adopting the 13 radiants as forming a single shower with a duration of more than 2 months and a radiant fixed at the point $47° + 44°$? If a display of this character can, by any combination of circumstances, be approved it would certainly do away with some of the complications and doubts now existing and permit us to cut down considerably the number of supposed radiants, as many of them must be duplicates of long-continuing showers. But theoretically stationary radiants of the nature indicated cannot be admitted, and Dr. Kleiber has shown that if meteor showers are formed by rings or ellipses then the latitude of their radiants must remain constant while the longitude increases proportionately with the time. In other words the radiant must travel eastward amongst the stars and uniformly in a circle parallel with the ecliptic. The Perseids follow this rule but the Orionids apparently furnish a striking departure from it, for their radiant remains absolutely fixed at $92° + 15°$ during the 21 nights from Oct. 9 to 29 inclusive. The radiants of $\alpha - \beta$ Perseids in the foregoing table are also immovable, and this observational fact can hardly arise from a deception. It is true that showers are so plentifully distributed over the celestial vault that in some cases they must supply a succession of radiants at nearly identical positions. But the number of supposed fixed radiants is so great and the data on which they rest so conclusive, that the chance grouping of different showers cannot be accepted as affording a sufficient explanation of them. So far as observations on this field permit a confident statement the writer would aver that the series of radiants representing a stationary shower are practically identical in position, and cannot therefore be induced by any arrangement of separate streams. The most careful observation at Bristol has failed to exhibit differences in position other than those obviously resulting from the trivial errors common to this work. There is a shower from the star η Aurigæ ($74° + 41°$) which, beginning at the Perseid epoch in August, is prolonged intermittantly through the remainder of the year and is still active in February according to several authorities.

Observers will find that the various peculiarities, connected with the radiation of meteors, require the most careful and patient study. The rapid shifting of the Perseid centre will be confirmed without difficulty but the visible behavior of the majority of other showers will, from their comparative feebleness, occupy more time and require a keener discernment. A vast number of meteor-paths, registered with the utmost accuracy, will be neces-

sary before anything like a conclusive test can be applied. Indeed the work seems better suited to professional astronomers than to amateurs who can rarely find opportunity to devote their nights with steady persistency, year after year, to the settlement of intricate questions of the kind alluded to.

It is fortunate that the derivation of radiants is not wholly dependent upon one method or upon the efforts of a single observer. By pre-arranging simultaneous observations two persons at different stations may register a number of the same meteors and in every such case the pair of paths will be divergent from the radiant. Thus a single meteor accurately recorded at two places suffices to indicate a good radiant, whereas an isolated observer, in deducing a centre from his individual results, must gather at least 5 or 6 paths before a reliable position can be obtained. And there is always an element of doubt attached to the latter because the observer has no absolute proof that he has correctly apportioned the meteors to their various radiants. He is justified from the visible features of a meteor, in assigning the place of its radiant, but the evidence he possesses is not always conclusive. It is therefore impossible to avoid occasional error though the discrimination gained by experience will generally lead him aright. In the case of a double observation of a meteor its radiant is indisputable as it rests not upon an assumption but upon an observational fact. Of course the character of the two observations come in as an important factor, but we are only alluding to paths recorded by capable persons. for rough work in this department is of no value whatever. Observers have often concerted together for the contemporaneous watching of meteors with the view to determine their real paths in the atmosphere, but the writer has never heard that such watches were instituted for the main or sole purpose of detecting radiants. Yet they might be undertaken successfully, and indeed some such plan is really necessary for the detection of very feeble showers. The results that might be accumulated by two persevering observers working systematically would vastly exceed that accruing from independent effort, for one person watching the sky during 5 or 6 hours may scarcely obtain more than 5 or 6 radiants, but if he combines with another observer and the collective results are compared, it is probable 3 or 4 times as many radiants would be found and the latter, being positions proving themselves, would be of thoroughly trustworthy character.

VARIABLE STARS. III.

J. A PARKHURST.

The preceding article in this series gave the methods used for observing variables and recording the observations. The present article will tell how to reduce the observations and draw from them the facts sought in regard to the behavior of the stars.

When a variable has been observed by Argelander's method, at frequent intervals for a time, the observations themselves furnish values for the brightness of the comparison stars. These stars then form a "light scale" by means of which numerical values for the brightness of the variable at the time of each observation can be deduced; since we have from each observation a value of the brightness of the variable in terms of the brightness of one or more comparison stars. This will be best understood by having an actual example before us, and following the reductions step by step. I will use for an illustration my observations of 4557 S Ursæ Majoris, from May to December 1893, omitting for the sake of simplicity the comparisons of the comparison stars among themselves.

OBSERVATIONS OF 4557 S URSÆ MAJORIS.

1893	May	11	*d* 2 *v*, *v* 3 *f*.
		17	*d* 2 *v*, *v* 4 *f*.
		27	*d* 2 *v*, *v* 3 or 4 *f*.
	June	19	*f* 1 *v*, *v* 1 *g*.
	July	1	*h* 1 *v*, *v* 2 *k*.
		10	*h* 2 *v*, *v k* or *v* 1 *k*.
	Aug.	2	*m* 2 or 3 *v*, *n v* or *n* 1 *v*, *v* 3 or 4 *o*.
		11	*n v* or *n* 1 *v*, *v* 1 or 2 *o*.
		16	*n* 1 *v*, *v* 1 *o*.
		26	Moonlight, *v* not held.
	Sept.	2	*n* 2 *v*, *v o*, *v* 1 *p*.
		6	*v* about = *o*, faint, seeing bad.
		26	*v* about = *m*, difficult, moonlight.
	Oct.	7	*v m*, *v* 1 or 2 *n*, low.
		9	*l* 1 or 2 *v*, *v* 2 *m*, seeing good.
		22	*g* 2 *v*, *v* 3 or 4 *l*, *v* 3 *k*.
		30	*v* 3 *l*, *v g*, *f* 2 *v*, *v* 3 *k*.
	Nov.	2	*f* 1 *v*, *v* 1 *g*.
		10	*f v*, *v* 2 *g*, *d* 4 *v*
		17	*v* 3 *f*, *d* 3 or 4 *v*
		30	*v* 5 *f*, *d* 3 *v*
	Dec.	3	*v* 3 *f*, *d* 3 or 4 *v*.

First we will form the light scale. The observations of May 11, furnish a value for the interval in steps between the stars *d* and *f*. Since *d* is 2 steps brighter than *v* and *v* 3 steps brighter than *f*, it follows that *d* is 5 steps brighter than *f*. By taking the mean of all the intervals from the observations in which *v* is between *d* and *f* in brightness, a good value may be obtained. Selecting similar combinations from the observations of each date, we can get values for the step intervals between all the comparison stars used. Intervals found by subtraction are not so reliable, and should only be used when better ones are wanting. The work will stand as in the following table, in which all the intervals between *d* and *f* are ranged under the heading *d f*, and similarly for the intervals between the other stars

		d f
May	11	5
	17	6
	27	5.5
Nov.	10	4
	17	6.5
	30	8
Dec.	3	6.5
	7)41.5	
	Mean *d* 5.9 *f*	

		f g
June	19	2
Oct.	30	2
Nov.	2	2
	10	2
	4) 8	
	Mean *f* 2.0 *g*	

		g k
Oct.	22	5
	30	3
	2) 8	
	Mean *g* 4.0 *k*	

		h k
July	1	3
	10	2.5
	2) 5.5	
	Mean *h* 2.8 *k*	

		m n
Oct.	7	1.5

		m o
Aug.	2	6

		n o
Aug.	2	4
	11	2
	16	2
Sept.	2	2
	4)10	
	Mean *n* 2.5 *o*	

		n p
Sept.	2	3

		o p
Sept.	2	1

		l m
Oct.	9	3.5

		g l
Oct.	22	5.5
	30	3
	2) 8.5	
	Mean *g* 4.3 *l*	

		k l
Oct.	30	0.0

		f l
Oct.	30	5

		f k
Oct.	30	5

		d g
Nov.	10	6

It will be noticed that these intervals do not exactly agree among themselves. For instance we have the intervals *f* 2 *g* and *g* 4 *k* from which the interval *f* 6 *k* would result. But that interval observed directly was *f* 5 *k*. Since the value *f* 6 *k* depends on six observations while *f* 5 *k* depends on only one, by giving weights according to the number of observations the mean value *f* 5.9 *k* would result. The following method will be convenient to make use of all the above intervals, each with its proper weight, in forming the light scale.—Assign the arbitrary value 0 to the faintest star used; in this case $p = 0$. For the next brighter star, *o*, we find from the observation of Sept. 2, the interval *o* 1 *p*, hence $o =$

$p + 1.0 = 1.0$. For the next brighter star, n, we have from the above table,

$$n = p + 3.0 = 0.0 + 3.0 = 3.0$$

also $$n = o + 2.5 = 1.0 + 2.5 = 3.5$$

These two values for n can be combined by multiplying each by the number of observations on which it depends, and dividing the sum of the products by the sum of the number of observations. Thus—

$$\begin{aligned} n = p + 3.0 = 0.0 + 3.0 = 3.0 \times 1 &= 3.0 \\ = o + 2.5 = 1.0 + 2.5 = 3.5 \times 4 &= 14.0 \\ 5) \quad & 17.0 \\ \text{Mean, } n = \quad & 3.4 \end{aligned}$$

By proceeding in this manner with each brighter star successively the scale values for all will be obtained. The following table shows all the work—

$$\begin{aligned} p &= 0 \\ o &= p + 1.0 = 0.0 + 1.0 = 1.0 \\ n &= p + 3.0 = 0.0 + 3.0 = 3.0 \times 1 = 3.0 \\ &= o + 2.5 = 1.0 + 2.5 = 3.5 \times 4 = 14.0 \\ & \qquad\qquad 5) \quad 17.0 \\ & \qquad \text{Mean, } n = \quad 3.4 \end{aligned}$$

$$\begin{aligned} m &= n + 1.5 = 3.4 + 1.5 = 4.9 \times 1 = 4.9 \\ &= o + 6.0 = 1.0 + 6.0 = 7.0 \times 1 = 7.0 \\ & \qquad\qquad 2) \quad 11.9 \\ & \qquad \text{Mean, } m = \quad 6.0 \end{aligned}$$

$$\begin{aligned} l &= m + 3.5 = 6.0 + 3.5 = 9.5 \\ k &= l + 0.0 = 9.5 + 0.0 = 9.5 \\ h &= k + 2.8 = 9.5 + 2.8 = 12.3 \\ g &= k + 4.0 = 9.5 + 4.0 = 13.5 \times 2 = 27.0 \\ &= l + 4.3 = 9.5 + 4.3 = 13.8 \times 2 = 27.6 \\ & \qquad\qquad 4) \quad 54.6 \\ & \qquad \text{Mean, } g = \quad 13.7 \end{aligned}$$

$$\begin{aligned} f &= g + 2.0 = 13.7 + 2.0 = 15.7 \times 4 = 62.8 \\ &= l + 5.0 = 9.5 + 5.0 = 14.5 \times 1 = 14.5 \\ &= k + 5.0 = 9.5 + 5.0 = 14.5 \times 1 = 14.5 \\ & \qquad\qquad 6) \quad 91.8 \\ & \qquad \text{Mean, } f = \quad 15.3 \end{aligned}$$

$$\begin{aligned} d &= f + 5.9 = 15.3 + 5.9 = 21.2 \times 7 = 148.4 \\ &= g + 6.0 = 13.7 + 6.0 = 19.7 \times 1 = 19.7 \\ & \qquad\qquad 8) \quad 168.1 \\ & \qquad \text{Mean, } d = \quad 21.0 \end{aligned}$$

Light scale.

$$\begin{aligned} p &= 0 \\ o &= 1.0 \\ n &= 3.4 \\ m &= 6.0 \\ l &= 9.5 \\ k &= 9.5 \\ h &= 12.3 \\ g &= 13.7 \\ f &= 15.3 \\ d &= 21.0 \end{aligned}$$

We are now prepared to assign numerical values to the brightness of the variable at the time of each observation. Here again we must take the mean of slightly different values, for instance for May 11 we have $d\ 2\ v$, whence $v = 19.0$, also $v\ 3\ f$, whence

$v = 18.3$; the most probable value will be the mean of the two, or $v = 18.7$. Proceeding in this way with the observation of each date we have

Date.	Observed.	Mean.
1893 May 11	19.0, 18.3,	18.7
17	19.0, 19.3	19.2
27	19.0, 18.8	18.9
June 19	14.3, 14.7	14.5
July 1	11.3, 11.5	11.4
10	10.3, 10.0	10.2
Aug. 2	3.5, 2.9, 4.5	3.6
11	2.9, 2.5	2.7
16	2.4, 2.0	2.2
26		
Sept. 2	1.4, 1.0, 1.0	1.1
6		1 ±
26		6 ±
Oct. 7	6.0, 4.9	5.5
9	8.0, 8.0	8.0
22	11.7, 13.0, 12.5	12.4
30	12.5, 13.7, 13.3, 12.5	13.0
Nov. 2	14.3, 14.7	14.5
10	15.3, 15.7, 17.0	16.0
17	18.3, 17.5	17.9
30	20.3, 18.0	19.2
Dec. 3	18.3, 17.5	17.9

These results can be represented to the eye on squared paper by laying off the dates horizontally and the brightness vertically, and drawing a smooth curve passing as nearly as possible through the points thus located. This curve will show approximately the time of maximum or minimum, and the corresponding brightness expressed in terms of the light curve. The time of maximum or minimum can be more accurately determined by bisecting the horizontal lines connecting corresponding points on the ascending and descending branches of the curve, drawing a line through the points thus located, and prolonging it till it intersects the light curve. This point of intersection will be the maximum or minimum as the case may be.

The accompanying charts are copies of small portions of the Durchmusterung charts, and are taken by the kindness of the author from Pickering's "Variable Stars of Long Period." They are two degrees square, with the variable near the centre enclosed in a small circle. The stars are all north of $+53°$ Decl. and therefore do not set to observers in northern and central United States. The following table shows their peculiarities; the data are taken from Chandler's "Second Catalogue of Variable Stars."

No.	Star Name	Place for 1900.0 R. A.	Decl.	Redness	Magnitude Max.	Min.	Period days.
		h m s	° ′				
107	T Cassiopeiæ	0 17 49	+ 55 14.3	7.3	7.0 — 8.0	11.0 — 11.2	445.0
432	S Cassiopeiæ	1 12 18	+ 72 5.1	6.7	6.7 — 8.6	< 13.5	610.5
793	T Persei	2 12 12	+ 58 29.5	4	8.2	9.3	Irreg.
814	S Persei	2 15 41	+ 58 7.8	5.0	8.5	13	"
1855	R Aurigæ	5 9 13	+ 53 28.4	6.5	6.5 — 7.8	12.5 — 12.7	460.6
2478	R Lyncis	6 53 3	+ 55 28.1	4.8	7.8 — 8.0	< 13	380.0
3825	R Ursæ Majoris	10 37 34	+ 69 18.0	1.6	6.0 — 8.2	13.2	302.1
4511	T Ursæ Majoris	12 31 50	+ 60 2.3	2.0	6.0 — 8.5	12.2 — 13	257.2
4557	S Ursæ Majoris	12 39 34	+ 61 38.4	3.2	6.7 — 8.2	10.2 — 11.5	226.1

The periods of all the above stars except R Aurigæ and R Lyncis are subject to variations, more or less irregular, ranging from 20 to 50 or more days above or below the period assigned. The laws governing these variations are not all well known, hence more observations are desired.

The table accompanying the plate gives the designation, place, and approximate magnitude (to the nearest unit) of Pickering's comparison stars for the variables charted. The comparison stars down to the 10th magnitude are lettered on the charts. It is an excellent plan for the observer to make about a three-fold enlargement of each chart in his note book, locating carefully thereon the comparison stars down to a magnitude below the limit of vision of his telescope. (See October POPULAR ASTRONOMY, page 91.)

FIRST OBSERVATIONS OF THE SUN AND MOON.

MARY E. BYRD.*

I. QUESTIONS.

1. At what point on the horizon does the Sun set on some evening in January?

2. In eight or ten days can you detect a change in the sunset point? Is it moving north or south?

3. Five or six weeks after the January observation, how many degrees is this point from the west point?

4. If observations are made weekly, is the sunset point found moving uniformly along the horizon, or is the number of degrees passed over greater in some weeks than in others?

5. How do you account for the motion of the sunset point?

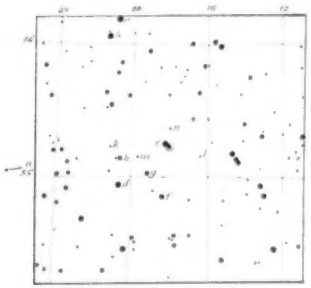
6. Can you find a time when for a few nights this point appears to be stationary?

7. When does the Sun set nearest to the south point?

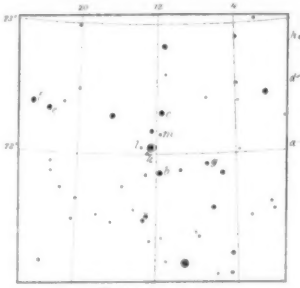
8. How many degrees is it then distant from the west point?

* Director of the Observatory at Smith College, Northampton, Mass.

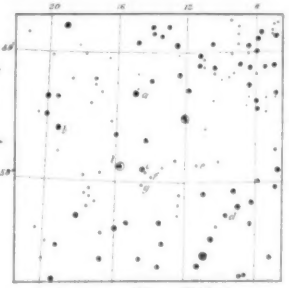
CIRCUMPOLAR VARIABLE STARS OF LONG PERIOD.



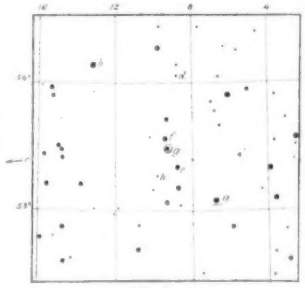
107 T CASSIOPEIÆ.
R.A. $0^h\ 17^m.8$ DEC. $+55°\ 14'$



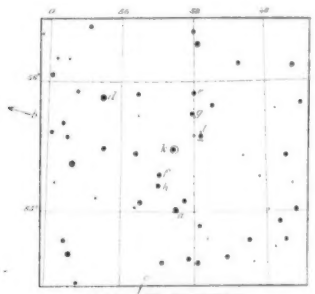
432 S CASSIOPEIÆ.
R.A. $1^h\ 12^m.3$ DEC. $+72°\ 5'$



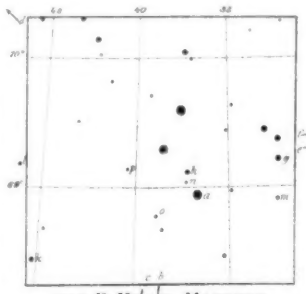
793 and 814, T and S PERSEI.
R.A. $2^h\ 12^m.2$ DEC. $+58°\ 29'$
$2^h\ 15^m.7$ $58°\ 8'$



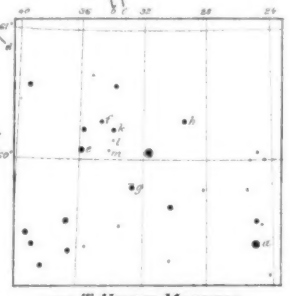
1855 R. AURIGÆ.
R.A. $5^h\ 9^m.2$ DEC. $+53°29'$



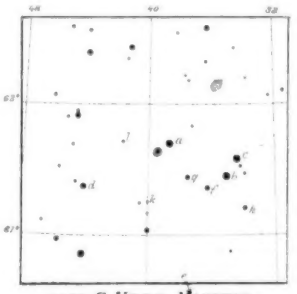
2478 R. LYNCIS.
R.A. $6^h\ 53^m.1$ DEC. $+55°\ 29'$



3825 R. URSÆ MAJORIS.
R.A. $10^h\ 37^m.6$ DEC. $+60°\ 18'$



4511 T URSÆ MAJORIS.
R.A. $12^h\ 31^m.9$ DEC. $+60°.3'$



4557 S URSÆ MAJORIS.
R.A. $12^h\ 39^m.6$ DEC. $+61°39'$

9. Do the times of sunset vary uniformly from night to night?

10. How closely do the observed times of sunset agree with the almanac times?

11. If the setting point of the Sun is found, for example, to be ten degrees south of the west point on a certain evening, how far from the east point is it observed to rise on the preceding or on the following morning?

12. What is the noon altitude for one of these two days?

13. Having given the Sun's declination, how can you test the accuracy of this observation?

14. Can you detect any variation in the Sun's noon altitude in less than a week?

15. When the sunset point is moving south, how is the noon altitude changing?

16. When the sunset point is moving north, how is the noon altitude changing?

17. What is the noon altitude when greatest? When least?

18. At what times in the year are the greatest and least altitudes observed?

19. From these observations, how can you obtain approximately the angle between the ecliptic and the celestial equator?

20. From these observations how can you obtain approximately the latitude of the place?

21. Does the Sun ever pass through your zenith?

22. How accurately can you find apparent noon from two observations of the Sun, taken when it has the same altitude a little before and a little after meridian passage?

23. What is the difference between noon as shown by the clock and by the Sun on the noon mark?

24. Why do the noons not agree?

25. What constellation is seen in the west after sunset along the course which the Sun has just travelled?

26. From month to month do you find the same constellation there?

27. Do you always see the same constellation in the east, in the Sun's path just before sunrise?

28. What apparent motion of the Sun do these observations indicate?

29. Fixing the Sun's daily path with regard to the horizon by the points of rising, southing and setting, do you find a change in this path from month to month?

30. In what month is the path shortest and nearest to the horizon?

31. In what month is it longest and nearest to the zenith?

32. At what times in the year are the paths in a similar position with regard to the horizon?

33. Locating the Sun with regard to the horizon, what is its altitude and azimuth at a particular hour and minute?

34. How great is the change in these coördinates in an hour?

35. Which coördinate is changing the more rapidly at noon?

36. Two or three hours before sunset which is changing the more rapidly?

37. What is the hourly rate of the Sun's apparent motion?

38. Do you note any difference in the rate of this motion when it is an hour high and when it is half an hour high?

39. How long does it take the Sun to set, that is how long is the interval between the disappearance of the lower and upper limbs?

40. Does this interval vary in different months of the year?

41. Can you detect any difference in the size or form of the Sun when seen in different parts of the sky?

42. Is there any variation in the color of the Sun in one day, or from day to day?

43. Testing sunlight by its power to penetrate clouds, is there any difference in that which comes from the limb and from the centre of the Sun?

44. About the times of sunspot maximum if you look at the Sun through dark glasses can you see any spots?

45. What is the color of the Moon?

46. Are there variations in the color in one night?

47. Is the color different on different nights?

48. What is the appearance of the Moon when seen in broad daylight?

49. How do you describe the appearance which you designate as the "old Moon in the new Moon's arms?"

50. Do the dark and illuminated parts seem to belong to the same circle?

51. If not, which part belongs to the larger circle?

52. On a given evening what proportion of the disc is seen?

53. Is the bounding line between the light and dark portions smooth or broken?

54. At any particular time does the terminator form a convex or a concave boundary for the illuminated portion of the Moon? Can you lay down a general rule for different phases?

55. Viewed by the unaided eye, when, if ever, is the terminator a straight line?

56. Does the Moon appear full to the naked eye for three or four hours?

57. Which limb first becomes defective?

58. How are the dark markings located on the disc?

59. What proportional part of the visible disc do they occupy?

60. Does the color of the markings vary?

61. Do they change their position relatively to the limb, to the terminator, or to one another?

62. How would you prove that the Moon in all its phases is the same Moon?

63. When the Moon is full on any given evening, how does its time of rising compare with the time of sunset?

64. At what time does the Moon set on two or three successive nights?

65. How do these observed times agree with the almanac times?

66. Does the Moon rise and set every day?

67. In September or October can you find a time when the Moon stays above the horizon more than twelve hours? Less than twelve hours?

68. What marked peculiarity do you notice about the rising of the Moon when it is nearly full in September and October?

69. Where do you look for the Moon a few days before it is new?

70. How short a time before new Moon can you see the Moon?

71. How soon after new Moon can you see the Moon?

72. Why can you not see it at the instant of new Moon, or at least an hour or two after that time?

73. Which way do the horns of the new Moon point? Why?

74. When you see the crescent Moon in the East, which way do the horns then point? Why?

75. By means of the celestial globe and a disc of paper for the Moon, how accurately for a particular day and hour can you predict the direction in which the horns will point?

76. Locating the Moon with regard to the horizon, what is the altitude and azimuth at a given hour and minute?

77. In how short a time are you sure of detecting a change in these coördinates?

78. During a particular day, between what limits approximately do the altitude and azimuth of the Moon vary?

79. At a given time, how many degrees is the Moon above or below the ecliptic?

80. Measuring along the ecliptic how many degrees is it then east or west of the vernal equinox?

81. Estimating distances directly from the celestial equator and vernal equinox, what is the Moon's right ascension and declination?

82. How accurately can you obtain these coördinates by mapping the Moon with stars near it?

83. Can you detect a change in these coördinates from night to night? In a single night?

84. On a given night in what constellation is the Moon?

85. How do you reconcile the constellation in which the Moon is found in the sky with the place of the Moon as given in the *Old Farmer's Almanac?*

86. In what direction does the Moon appear to move?

87. What is the hourly rate of the apparent motion?

88. In what direction does the Moon move among the stars?

89. What is the hourly rate of this motion?

90. Through what constellations does the Moon pass in a given lunar month?

91. Does it pass through the same constellations in different months?

92. Fixing its path by bright stars, does the path vary from month to month?

93. Fixing the Moon's path in reference to the horizon by the points of rising, southing and setting, do you find a change from night to night? From month to month?

94. How does the full Moon compare in size with the Sun?

95. On a given day, does the Moon rise north or south of the sunrise point?

96. On a given day, does the Moon set north or south of the sunset point?

97. Is the meridian altitude of the Sun or the Moon greater on any particular day?

98. If you fix the paths of the Sun and Moon by their points of rising, southing and setting, how do these paths compare on any given day?

99. Having found the relative positions of these two paths for one day, will this position hold true for other days in different months?

II.

Suggestions.

The preceding questions with few exceptions can be brought into two groups, one dealing with the position and motion of the Sun and Moon, the other treating of the physical characteristics of these bodies, their form, size, color and surface markings.

It is possible even without a telescope to do a little in studying the solar disc. One can at least put to the test his vague notions that the sun is not always of the same size, that it has been seen elliptical in outline and that its color varies all the way from dazzling white tinged with yellow to a dull, deep red. These winter days offer abundant opportunity to note how sunlight is affected by passing through cloud-layers of different thickness, and any one who watches the sun under a cloud for several days should obtain satisfactory proof for or against the text-book dictum that all parts of the sun are not equally bright. It is no objection whatever to such observations as these that they deal mainly with optical delusions and effects of the atmosphere. If one is ever to divine from appearances in the sky what belongs in very truth to a heavenly body and what must be traced to the observer and his surroundings, these tricks played by the air and our own eyes are precisely the very things to be investigated and it is well to begin with simple phenomena where the illusions stand out boldly.

In all observations connected with the Sun, spectacles with dark glasses are better than a piece of smoked glass held in the hand. The inexperienced observer gets a steadier view and both hands are left free. Two pairs of spectacles are needed when watching for sunspots and even then the glasses, un'ess they are very dark, must be smoked. The present year is a favorable time for finding spots on the Sun. There is a possibility any day that one may appear which is large enough to be seen without any magnifying power. During the past few months one of the students here has made a report of sunspots seen with the naked eye.

The sun is very bright and very far away. The Moon is our next-door neighbor and shows true neighborly kindness in being hospitable to every observer on the earth. Any one who has not made the experiment will doubtless be surprised to find out how much can be learned about the Moon's surface by simply looking at it. No matter how little is seen at first, it is only necessary to persevere and one by one details come out. A simple question is found to involve much more than appears at first sight. It needs more than a hasty glance to describe the ghost of a Moon which appears in broad daylight, looking like and yet unlike a little cloud.

All satisfactory study of the Moon's appearance must be accompanied by drawings of some kind. The poorest are usually better than none. In answering questions from 45 to 62 in the

preceding list, as many as eight or ten sketches should be entered in the note-book in connection with the descriptions. No one should omit careful and repeated observation with the naked eye, although final tests will naturally be made, if possible, with an opera glass. If the glass magnifies three or four diameters, a genuine beginning can be made in selenography, and for that it would be hard to find a better guide than Chapter V, in *Astronomy with an Opera Glass*, by Serviss.

To be Continued.

GLASS FOR OPTICAL INSTRUMENTS WITH ESPECIAL REFERENCE TO TELESCOPE OBJECTIVES.

J. A. BRASHEAR.*

When the glass for the 36-inch objective of the Lick Observatory was under process of manufacture, and many failures had been made in obtaining the crown disc, a very successful glass maker in this country came to the writer and suggested that he could make such a disc without any difficulty. After a brief conversation with the gentleman as to his plans, it was clearly evident that the sum of his knowledge about optical glass was that it should be *transparent* and free from bubbles. Many persons, not conversant with the conditions demanded in a piece of glass suitable for making a high class telescope objective, consider that transparency and freedom from bubbles are the most important elements to consider, whereas a piece of glass may be as "clear as crystal" and without a bubble to mar its beauty, yet be worthless in an optical sense.

The history and development of the optical glass industry is indeed a very interesting story, but as its general facts have been written many times, it is best that we give our readers information of a kind that will be of practical value. They will, however, desire to know something of the methods of manufacture.

In making window glass, plate glass, table-ware glass, etc. the furnaces for melting the material are large enough to have from four to a dozen or more pots placed in them, and these pots are used until they break or are burned out, but in making optical glass but one pot is placed in a small furnace. Great care must be taken in the preparation of the pot as the oxide of iron and other impurities, often constituents of the clay used in the manufacture of pots for melting glass in, would ruin the finer grades of optical glass.

* Optician, Allegheny, Penn.

After the pot is brought up to a pretty high temperature the "batch" or material for the glass is placed in the pot and allowed to subside by the softening of the more easily melted materials, and again filled up, three fillings being usually required.

While the "batch" is melting we will give the composition of a few of the various glasses used in optical work.

Guinand and Fraunhofer used for the flint glass for objectives for telescopes,

100 parts silica,
106 parts red oxide of lead,
43 parts carbonate of potash.

Bontemps used

100 parts silica,
100 parts red oxide of lead,
21.5 parts carbonate of potash,
5 parts nitrate of potash.

A standard "batch" used in France and England contains:

100 parts silica,
105 parts red oxide of lead,
20 parts carbonate of potash.
5 parts nitrate of potash.

For denser flints more oxide of lead is used and for lighter, less of the oxide, and there are very many variations, formulæ for which the writer has received from the younger Feil, but which need not be repeated here.

For the crown glass the "batch" is composed of

100 parts silica,
41.64 parts carbonate of potash,
9.46 parts red oxide of lead.
9.46 parts slacked lime,
1.90 parts nitrate of potash.

Another formula is,

100 parts silica,
42.66 parts carbonate of potash.
21.66 slacked lime,
2.22 parts nitrate of potash.

In this latter formula the lead is left out entirely.

The optical glass manufactory of Jena has added many new kinds of flint and crown glasses which are now at the command of the optician, and Mr. Mantois of Paris has also made a number of new kinds during the past few years, but the standard

flint and crown glasses for telescope objectives are practically those whose formulæ have been given above. Ordinary optical crown glass has an index of refraction for the D line of the spectrum of 1.51, but by the addition of baryta, this index has been increased to as high as 1.587.

Boro silicate flint glass has been made with an index for the D line as low as 1.55, while the dense yellow flint glass known as Faraday glass has an index for D equal to. 1.9626. But we must return to our glass melting furnace, and will find the "batch" melted and quite limpid. A "gathering" of it is now taken out on a rod called a punty, although a small pipe is frequently used so that the trial piece may be made something like the shape of a pear with a slight hollow blown in it. If the trial piece is found transparent and free from "seeds" which are imperfectly melted particles of silex or minute air bubbles, it is good enough for ordinary purposes for which glass is used in the arts, but for optical purposes it must now be stirred by a peculiar stirrer made of pot clay which is sometimes heated before being inserted in the pot. Our French optical glass makers call this stirrer Le Guinand, after the celebrated Guinand who first used this method of thoroughly mixing the glass. An iron bar called a crochet, bent at the end to insert in the clay stirrer, but which does not come in contact with the melted glass is put in an opening made for it in the Guinand and the glass is stirred thoroughly until it becomes so stiff by gradual cooling that it cannot well be stirred longer. For ordinary optical glass this one stirring usually suffices, but a second and even a third stirring is resorted to after the glass has been made softer by additional heating, if the highest grades of glass are desired.

This careful and prolonged stirring is one of the most difficult parts of the manipulation, as it usually requires two workmen to stand before the intensely heated furnace for two or three hours. When the stirrer is first introduced and the glass is limpid it can be moved around inside of the pot once a second, but at the close of the operation it requires five or six times as long to move it.

The stirrer must not touch the pot or some of the clay may be incorporated with the glass, and thus ruin it.

The purpose of this stirring is, to so thoroughly mix the glass that it will be as nearly equal in density throughout the mass as possible, and be free from striæ and other impurities that are, in part at least, eliminated in this way. After the final stirring, the next step is to thoroughly lute or stop every open place in the furnace so as to prevent any air from gaining admittance to it, and

then a slow process of cooling goes on for from four to eight days, according to the size of the pot and the amount of material contained in it. This slow cooling is not for the purpose of annealing the glass in a perfect manner, but to save the glass from being shattered into small fragments. With the slowest cooling, it is always very uncertain whether or not large pieces, unbroken, can be secured, for if a lump is *cracked* in any way it can never be reunited to make a perfect disc; hence it is that as the discs of optical glass increase in size their cost increases greatly, and justly so. The writer has seen some very odd looking shapes in the original blocks at the factory of Mr. Mantois in Paris, from which one would think it impossible to make a disc suitable for a large objective, but we all owe a debt of gratitude to Guinand for the beautiful process which takes hold of this rough and unshapely piece of glass and fits it for the optician's handiwork.

And now let us follow the block as it goes through the processes which make it suitable for a lens.

A superficial examination determines whether it has such serious defects as would make it useless to carry the manipulation further. This preliminary examination causes many pieces to be rejected or set aside to be utilized for plates good enough for some uses such as cheap photo lenses, opera glasses, etc. If however, on close examination, it is found suitable for a high class lens, any serious defects are either ground off on a mill or sawed off with a soft iron saw, using sand or emery, or with a diamond saw, *i. e.*, a soft iron saw with diamond dust hammered in its edge. Some times it is found necessary to grind more than half way through a block of glass to cut out an imperfection and this may be done with safety, and indeed it is possible to grind almost through a block of glass and save it, but if the cut goes entirely through, it will never reunite without a flaw, whereas, when the cut is not through, the opening, with its surrounding rough surfaces will slowly rise to the top when the piece is softened in its secondary heating, which we will presently notice.

To be Continued.

FAITH IN THE INTEGRITY OF THE INTERSTELLAR MEDIUM.

DE VOLSON WOOD.*

That space is not void is conceded. That it is filled with a medium capable of transmitting light and heat is not questioned. This medium is believed to be uniform in density and elasticity,

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but the exact nature of its constitution is unknown. Some believe it to be molecular like gas, while others question if its structure has been correctly defined. It makes no direct impression upon the senses, and is known only through effects produced; and yet, whatever be its nature, it is known to transmit a wave of light at the rate of 86,300 miles per second, there being, as a mean value, within the spectrum about 50,000 waves in an inch, or more than 60,000,000,000,000,000 in the distance passed over in one second. When it is considered that waves are transmitted through this medium in all conceivable directions with the same velocity, some faint conception may be had of its intense activity. The complicity of the waves is transcendent, for each shade of light has its own wave-length, there being about 36,000 waves to the inch in red light, and more than 64,000 in violet, and outside the visible spectrum there are less in number in one direction and more in the other. Every self-luminous body in the universe is imparting to this medium waves of these varying lengths, all travelling with a sensibly constant velocity. When it is considered that the countless number of stars and suns, scattered promiscuously throughout limitless space, are producing such waves radiating from each other in all possible directions, it would seem that, if they did not actually destroy each other, they would so interfere as to produce "confusion worse confounded" and the impressions upon the eye of an observer would be valueless. But, on the contrary, the scientist believes that this medium truly and faithfully transmits to the remotest space every wave imparted to it, preserving with the strictest integrity its individuality—except that planets and other solid bodies may destroy the waves they intercept.

A star ten or more years ago started a wave which just now, we will suppose, arrives at the Earth and writes its own record on some sensitized plates, though the star may be 6,000,000,000,000 miles away. From these impressions the physicist finds—perhaps—that the star is double, although the most powerful telescope had failed to divide it, that the two revolve about each other, and he determines their probable orbit, masses and velocities. Or, perhaps he finds, as in the remarkable star of 1892, that it changes from a star to a nebula in a few months. In all this, no question is raised in regard to the integrity of the record, nor whether in its long journey, any planet, sun, comet, meteorite or nebula has interfered to modify or in any way to corrupt the story it was commissioned to tell. What faith! But this is little more than the shadow of an illustration; for Herschel, the

astronomer, thought it probable that we can see nebulæ from which it has taken light 300,000 years to reach the Earth, during which time the interstellar medium has been faithful in transmitting at the rate of more than 11,000,000 miles per minute the impulse committed to it, notwithstanding its path has been crossed and recrossed by other waves without number. Pen cannot adequately describe the transcendent properties of this wonderful medium called the "luminiferous ether," nor too highly exalt that faith which enables one to implicitly believe the truthfulness of the stories committed to him. One is led to exclaim with the Psalmist "Oh Lord! how manifold are thy works, in wisdom thou hast made them all."—*Science, Nov. 3, 1893.*

THE FACE OF THE SKY.

CHARLOTTE R. WILLARD.

At about seven o'clock February first a bright star may be seen rising a little north of the east point of the horizon. This is Regulus (α Leonis), the heart of the Lion, and is the brightest star in the zodiacal constellation Leo. On the twenty-first of August the sun passes just below this star. Preceding Regulus are five stars which with it form the Sickle, Regulus being at the end of the handle. Near the upper part of the Sickle is the point in the heavens from which the November meteors seem to radiate. The second star from Regulus (γ Leonis) is a fine double; the components are separated by about 3″, and are of magnitudes 2 and 4; this is a binary with "period of 1,000 years or less."

Near the Sun's path and preceding Regulus by about 2½ hours is a hazy spot known as Præsepe or the Bee Hive in the constellation Cancer. An opera glass resolves this into a beautiful cluster.

A comparison of the colors of the bright stars now visible will be found interesting. Notice the contrast between the colors of Betelgeuse and Rigel by glancing quickly from one to the other. There is much to interest in the theory that the age of a star is indicated by its color.

About half way between Præsepe and Sirius is Procyon, the Little Dog Star, which is the only first magnitude star in the constellation Canis Minor. Its name signifies before the Dog, it rising a little earlier than Sirius. The motion of Procyon is evidently disturbed by an unseen companion, for which Mr. Burnham has in vain searched with the Great Lick Telescope.

"The Face of the Sky" occupies little space in the present issue, because of the large amount of matter to be presented on the phenomena for the year 1894. Those objects are mentioned which are appearing in the East and have not been noticed in preceding numbers.

Observatory on Mont Blanc.—We will soon give a picture of the Observatory on the summit of Mont Blanc, Switzerland, which is 15,780 feet above the level of the sea. It is the highest astronomical Observatory in the world, and has only recently been completed.

PHENOMENA DURING THE YEAR 1894.

H. C. WILSON.

Thinking that a general preview of the astronomical phenomena, which are to be expected during this year, would be of interest to our readers, we have prepared the following notes.

Eclipses.—There will be four eclipses, two of the Sun and two of the Moon, none of which will be of special interest. The first will be a *partial eclipse of the Moon* on March 21, beginning at $5^h\ 57^m$ A. M., and ending at $10^h\ 44^m$ A. M., central standard time. Only one-fourth of the Moon's diameter will be immersed in the Earth's shadow at the time of maximum eclipse.

The second will be an *annular eclipse of the Sun* beginning April 5 at $7^h\ 16^m$ P. M., and ending at $12^h\ 32^m$ A. M., April 6, central time. It will be visible as a partial eclipse in Asia, Alaska, and the eastern part of Europe. The path of the annular eclipse passes from the Indian Ocean across Hindostan, China, and Siberia, into Alaska.

The third will be a *partial eclipse of the Moon*, beginning Sept. 14 at $7^h\ 59^m$ P. M., and ending Sept. 15 at $1^h\ 04^m$ A. M. This will be visible throughout North and South America. The beginning will be visible in the western portions of Europe and Africa. Only 0.23 of the diameter of the Moon will be covered by the shadow at the middle of the eclipse.

The fourth will be a *total eclipse of the Sun*, beginning Sept. 28 at $9^h\ 1^m$ P. M. and ending Sept. 29 at $2^h\ 17^m$ A. M. central time. It will be visible mostly in inaccessible regions. The path of totality passes from Central Africa across the Indian Ocean to the south of Australia. As a partial eclipse it will be visible in the eastern part of Africa, Persia, Hindostan, the Indian Ocean, the southern part of Australia and one of the islands of New Zealand.

Transit of Mercury.—The planet Mercury will pass directly between the Earth and the Sun on Nov. 10, so that for over five hours it will be seen projected as a round black spot upon the disc of the Sun. The transit will begin at $9^h\ 55^m$ A. M., and end at $3^h\ 12^m$ P. M. central time. The accompanying diagram, Fig. 1, will indicate the course which Mercury is to take across the solar disc. This transit, which will be the last to occur during this century, will be visible throughout North and South America, and in the western parts of Europe and Africa. Before November we will give the necessary data for computing the times of the contacts for different localities.

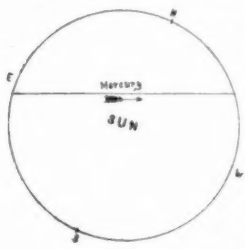

FIG. 1.

Occultations.—The usual number of occultations of stars by the Moon is to be expected. The lists of these for each month will be given one month in advance. We can, however, give only the data which apply to the occultations as seen from Washington, since these data are quite different for different localities, and the labor of calculating them for a sufficient number of points to make a general table even for the United States would be more than we can undertake. The Washington times will serve to call attention to the phenomena, but may be ex-

pected to be in error by many minutes, besides the difference in longitude for other places.

The Planets.—We have had the diagrams, Figs. 2 and 3, made in order to place before the eye of the reader the planets in their true places in their orbits, and relative positions with reference to the Earth and Sun. The circles represent the orbits of the planets, and their positions at the beginning and end of the year, and in some cases at the beginning of each month are marked upon the circles. It was impracticable to draw them all to the same scale, because of the enormous dimensions of the orbits of Uranus and Neptune.

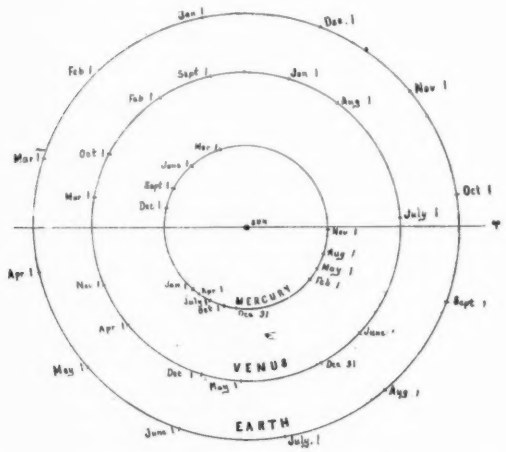

FIG. 2.—DIAGRAM SHOWING THE PLACES OF MERCURY, VENUS AND EARTH IN THEIR ORBITS DURING 1894.

At a glance one will see that Mercury makes a little more than four revolutions about the Sun, being seen from the Earth first on one side then on the other of the Sun. On Jan. 1 this planet as seen from the Earth, is to the right or west of the Sun. Toward the end of the month it will be behind the Sun, at superior conjunction. A few days before March 1 it will be at its greatest distance to the left or east of the Sun, and will therefore be visible in the evening just after sunset. About the middle of March Mercury will be in line between Earth and Sun, *i. e.*, at inferior conjunction, and invisible. A little study of the chart will show that we ought to expect to see Mercury as "evening star" in the latter part of February, the latter part of June and the middle of October, and as "morning star" about the middle of April, the first of August and the last of December.

In the same way we find that Venus will be "evening star" during January, but will pass between Earth and Sun in February, and after that will be "morning star," reaching her greatest distance to the right or west from the Sun in May. In November she will pass behind the Sun, becoming evening star again.

From Fig. 3 we see that Mars is just coming out from behind the Sun, and will not be in a very good position for three or four months yet, but that from July to the end of the year its position will be very favorable. Jupiter will be too close to the Sun for observation during May and June, and will be in best position in December. Saturn will be best seen in April and May, and will be invisible in

October. Uranus will be in best position in May and June, and Neptune in November and December. At the present time Mars, Saturn and Uranus are in that part of the sky which is visible in the morning, Jupiter and Neptune in the opposite region which is visible in the evening. Mars is rapidly leaving his companions behind, and at the end of the year will join Neptune and Jupiter.

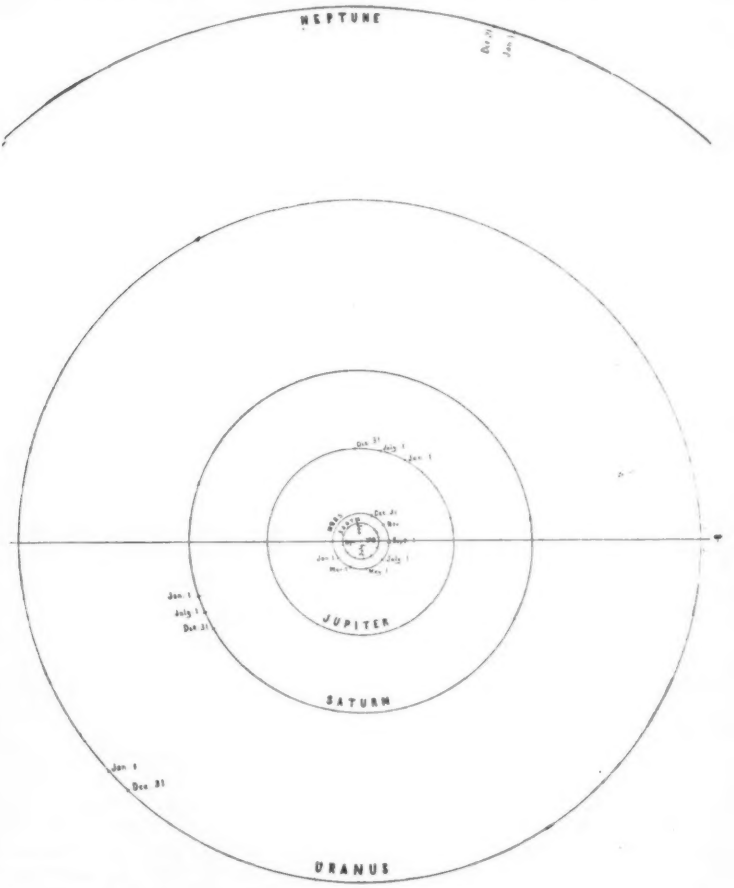

FIG. 3.—DIAGRAM SHOWING THE PLACES OF EARTH AND OUTER PLANETS IN THEIR ORBITS DURING 1894.

The chart, Fig. 4, shows the apparent paths which will be traced among the stars during the year by the planets Uranus and Saturn, and will enable the reader who is familiar with the constellations to identify the planets at any time.

Comets.—What new comets will be discovered of course we cannot predict, but two comets of short period are expected to return this year. The first, Tem-

pel II, the second comet of 1873, is due at perihelion April 20, and will be in good position for observation for several months after that time. It will be a telescopic comet. It was last seen in 1878, when it was observed for five months.

The second is Encke's periodic comet, which is not due at perihelion until Feb. 1895, but will be in best position for observation in December, 1894. This is also a telescopic comet, having a period of 3.3 years.

If the reader will refer to the plate of the Jupiter family of comets in the October number of POPULAR ASTRONOMY he will see the orbits of these comets and their relation to that of the Earth.

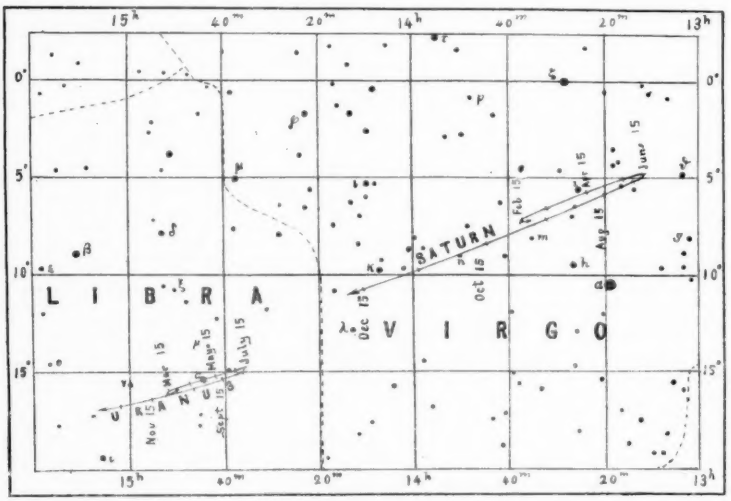

FIG. 4.—CHART SHOWING THE APPARENT PATHS OF SATURN AND URANUS AMONG THE STARS IN 1894.

The Phenomena of the Satellites.—The satellites of Mars are so small and faint that they are not likely to be seen by many amateurs. The most favorable time to make the attempt to see them will be in October when Mars is nearest the Earth.

The phenomena of Jupiter's four outer Satellites may be observed with a very moderate telescope. We will therefore give for each month the times of those phenomena which will be visible in the United States, and the configuration of the satellites at the most convenient hour for observation on each night. The diagram, Fig. 5, shows the apparent courses of the satellites around the planet for this year. The diagram gives the appearance seen in an inverting telescope. The vertical scale is made three times that of the horizontal scale in order to clearly separate the lines. Unfortuuately the arrows indicating the direction of motion have been omitted from the cut. It is easy, however, to remember that the motion in the upper half of each satellite orbit is toward the left, and in the lower half toward the right. It will be noticed that all the satellites except IV pass in front of the planet when going toward the left, and behind it when moving toward the right. Satellite IV barely skirts the upper and lower edges of the planet. The time when a satellite enters upon the right edge of the disc of

Jupiter is designated in the table on page 235 as *Tr. In.* (transit ingress); that when it leaves the left edge *Tr. Eg.* (transit egress). The time when the satellite coming from the left goes behind the planet is designated *Oc. Dis.* (occultation disappearance); when it emerges on the right *Oc. Re.* (occultation reappearance). When the satellite enters the shadow of the planet the designation is *Ec. Dis.* (eclipse disappearance); when it emerges from the shadow, *Ec. Re.* (eclipse reappearance). The shadow of the planet as seen from the Earth is sometimes projected toward the right, sometimes toward the left, and sometimes directly behind the planet, according to the position of the Earth with reference to the line passing through the Sun and Jupiter, so that the last mentioned phenomena occur in different apparent positions with reference to the planet at different times. In February the shadow of Jupiter will be projected toward the right, so that the eclipses all occur after the occultations and on the right side of the planet.

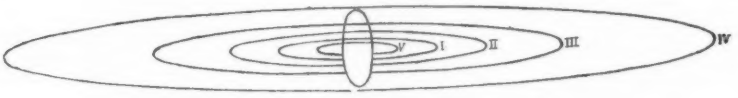

FIG. 5.—DIAGRAM SHOWING THE APPARENT COURSES OF THE SATELLITES OF JUPITER AROUND THE PLANET IN 1894.

The four diagrams at the top of page 234, marked *Phases of the Eclipses, etc.*, show where the observer should look for the disappearance and reappearance of each satellite. Satellite I is so near the planet that it enters the shadow while behind the planet, but reappears at the point marked $\frac{r.}{*}$ Satellite II disappears in the shadow at $\frac{d.}{*}$ very soon after emerging from occultation, and reappears at $\frac{r.}{*}$ The third satellite is so far out that both the disappearance and reappearance of eclipses occur quite a distance to the right of the planet, and IV does not enter the shadow at all. When the shadow of a satellite crosses the disc of the planet it is seen as a round black spot entering on the right and passing off the left edge. The beginning of this phenomenon is designated *Sh. In.* (transit of shadow ingress), and the end *Sh. Eg.* (transit of shadow egress).

The configuration of Jupiter's satellites will be indicated, as for February on page 234, for a given hour of each night, the light disc representing the planet and the dots the relative positions of the satellites. The numerals indicate the numbers of the satellites, and also the direction of their motions. The latter is always from the dot toward the numeral. A light disc at the left side of the page indicates that the satellite, whose numeral is attached, is projected upon the face of the planet; a black disc on the right, that the satellite is invisible by occultation or eclipse.

Five of the satellites of Saturn are usually visible with a telescope of moderate power. As they are best seen when at their greatest distances to the right or left of the planet (elongations), we will give each month the times of the eastern elongations. The western elongations will occur just half way between the eastern; and the positions of the satellites at other times can be interpolated with the aid of a diagram which we will give in our next number. The rings of Saturn will be in good position for observation this year.

The satellites of Uranus and Neptune are too faint to be seen except with large telescopes.

PLANET NOTES FOR FEBRUARY.

Mercury will be "evening star" during February. During the first half of the month he will be close to the Sun, but in the latter part will be visible to the naked eye for a short time after sunset. He will be at greatest elongation, east from the Sun 18°, on the evening of Feb. 25. His greatest brilliancy will be attained on the evening of Feb. 21. Mercury will be ten degrees due south from Venus at $9^h\ 41^m$ P. M. Feb. 8, central time.

Venus will be visible as evening planet for but a few days in February. On the 16th, at $3^h\ 04^m$ A. M., she will be at inferior conjunction, *i. e.*, between the Earth and Sun. Venus will be in conjunction with the crescent Moon, 11° north of the latter, at $3^h\ 03^m$ P. M. Feb. 6.

Mars will be visible in the southeast after 4^h A. M., but at too low an altitude for good observations in our latitude.

Jupiter will be at quadrature 90° east from the Sun Feb. 11, at $1^h\ 52^m$ A. M. He will be in excellent position for observation during the early part of the night. Jupiter will be in conjunction with the Moon, 4° 24′ north of the latter, Feb. 13 at $3^h\ 16^m$ A. M.

Saturn may be observed after midnight. Look toward the southeast in the constellation Virgo, about 5° northeast from the star Spica. The rings of the planet are easily seen with quite a small telescope. They are now turned at an angle of 14° to the line of sight, so that with telescopes of moderate power the divisions may be seen. Saturn's apparent motion among the stars during February will be westward. He will be in conjunction with the Moon, 4° north, at $8^h\ 02^m$ P. M. Feb. 23.

Uranus rises about midnight, and is in position for observation from 3 to 6 A. M. He is in the constellation Libra, about 1° 45′ east and 26′ south of the star α. Uranus will be at quadrature, 90° west from the Sun, Feb. 3 at $7^h\ 04^m$ P. M. He will be stationary in right ascension Feb. 18, and after that will move slowly westward. He will be in conjunction with the Moon, 3° 36′ north, at $9^h\ 58^m$ A. M. Feb. 25.

Neptune will be at quadrature, 90° east from the Sun, Feb. 29 at $2^h\ 36^m$ A. M. He will be in good position for observation during February. He is almost stationary in Taurus, a little more than one-third of the way on a straight line from ι to ε Tauri. There is no star of equal brightness, *i. e.*, 8th magnitude, within a radius of 1°.

Plate XI gives a photographic reproduction of a negative of a portion of the constellation Taurus, taken at Goodsell Observatory on the night of Nov. 17 by H. C. Wilson, with a 2½-inch camera. The camera was attached to the 8-inch photographic telescope, driven by clockwork, and corrected occasionally by the observer with a second telescope. The photograph was taken for the purpose of showing the place of Neptune with reference to the small stars, from which the amateur has difficulty to distinguish it. The planet is in the center of the plate near the point of the arrow. There is a diamond-shaped group of very faint stars which can only be seen with a magnifying glass, between the point of the arrow and Neptune. In order to enable the reader to identify the brighter stars we have marked upon the plate the Greek letters by which they are known, as well as the right ascension and declination lines. Toward the bottom of the plate is the familiar group of the Hyades with the bright red star Aldebaran (α). At the top of the plate are the bright stars ζ and β. The latter is photographically brighter than Aldebaran. The course of Neptune is diagonally across the plate. At pres-

PLATE XI.

Photograph of the region about Neptune in Taurus; taken with a 2½ inch camera at Goodsell Observatory, Nov. 7th, 1893; exposure 40 minutes.

ent the planet is near the feather end of the arrow, and moving very slowly toward the lower right hand corner of the plate. After March 20 it will move toward the upper left hand corner of the plate until Sept. 20, when it will be a little east and south of the star τ. After that time it will again move westward for a few months. We hope that this plate and the explanation will enable many amateurs to be sure that they have seen Neptune.

Planet Tables for February.

Date. 1894.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
		MERCURY.			
Feb. 5	21 41.7	− 15 51	7 41 A. M.	12 38.1 P. M.	5 35 P. M.
15	22 49.2	− 8 18	7 36 "	1 06.1 "	6 36 "
25	23 40.4	− 0 37	7 17 "	1 17.9 "	7 19 "
		VENUS.			
Feb. 5	22 11.8	− 3 43	7 19 A. M.	1 08.3 P. M.	6 57 P. M.
15	21 49.5	− 4 12	6 20 "	12 06.7 "	5 54 "
25	21 28.2	− 6 00	5 26 "	11 06.2 A. M.	4 46 "
		MARS.			
Feb. 5	17 35.5	− 23 28	4 09 A. M.	8 32.6 A. M.	12 56 P. M.
15	18 05.8	− 23 43	4 01 "	8 23.5 "	12 46 "
25	18 36.2	− 23 37	3 52 "	8 14.6 "	12 37 "
		JUPITER.			
Feb. 5	3 20.0	+ 17 34	11 00 A. M.	6 15.6 P. M.	1 32 A. M.
15	3 23 4	+ 17 49	10 22 "	5 39.6 "	12 57 "
25	3 28.0	+ 18 08	9 46 "	5 04.9 "	12 24 "
		SATURN.			
Feb. 5	13 37.0	− 7 19	10 56 P. M.	4 30.8 A. M.	10 05 A. M.
15	13 36.5	− 7 13	10 16 "	3 51.0 "	9 26 "
25	13 35.4	− 7 04	9 35 "	3 10.5 "	8 46 "
		URANUS.			
Feb. 5	14 51.7	− 16 02	12 51 A. M.	5 49.2 A. M.	11 47 A. M.
15	14 52.0	− 16 04	12 12 "	5 10.1 "	10 08 "
25	14 51.9	− 16 03	11 33 P. M.	4 30.7 "	9 28 "
		NEPTUNE.			
Feb. 5	4 37.8	+ 20 34	12 03 P. M.	7 33.0 P. M.	3 03 A. M.
15	4 37.6	+ 20 34	11 23 "	6 53.5 "	2 24 "
25	4 37.6	+ 20 35	10 44 "	6 14.2 "	1 44 "
		THE SUN.			
Feb. 5	21 17.8	− 15 45	7 15 A. M.	12 14.3 P. M.	5 14 P. M.
15	21 57.3	− 12 29	7 01 "	12 14.3 "	5 28 "
25	22 35.5	− 8 53	6 45 "	12 13.2 "	4 41 "

Phases and Aspects of the Moon.

Central Time.

	d	h m
Apogee	Feb. 1	4 00 P. M.
New Moon	" 5	3 45 P. M.
First Quarter	" 13	4 43 A. M.
Perigee	" 17	3 18 P. M.
Full Moon	" 19	8 17 P. M.
Last Quarter	" 27	6 28 A. M.

Occultations Visible at Washington.

Date 1894.	Star's Name.	Magnitude.	IMMERSION Washington M. T. h m	IMMERSION Angle f'm N pt. °	EMERSION Washington M. T. h m	EMERSION Angle f'm N pt. °	Duration h m
Feb. 11	19 Arietis	6	6 49	76	8 02	226	1 13
12	ζ Arietis	5	11 13	97	12 07	237	0 54
16	c Geminorum	6	17 17	59	17 49	332	0 32
20	σ Leonis	4	9 55	152	10 58	277	1 03

Jupiter's Satellites for February.

Phases of the Eclipses of the Satellites for an Inverting Telescope.

I. III.

II. IV. No Eclipse.

Configuration at 8h for an Inverting Telescope.

Day.	West	East.
1	·3· ○ ·1 2· ·4	
2	.3 2· ·1 ○ ·4	
3	·3 ·2 ○ 1· 4·	
4	·1 ○ ·3 ·2 4·	
5	○ 1·2· 4· ·3	
6	2. ○ 4· 3. ·1●	
7	4· 1· ○ 3· ·2●	
8	4· 3· ○ ·1 2·	
9	4· ·3 1·2· ○	
10	4· ·3 ·2 ○ 1·	
11	·4 ·1 ○ ·2 ·3●	
12	·4 ○ 1· 2· ·3	
13	·4 2· ○ 3· ·1●	
14	·4 1·2○ 3·	
15	3· ○ ·4 ·1 2·	
16	3· 1· 2· ○ ·4	
17	·3 ·2 ○ ·1 ·4	
18	·1 ○·3 ·2 .4	
19	○ 1· 2· ·3 ·4	
20	2· ·1 ○ ·3 4·	
21	○ 1· ·2 ○ 3· 4·	
22	3· ○ ·1 ·2 4·	
23	○ 2· 3· 1· ○4·	
24	·3 ·2 4· ○ ·1	
25	4· ·1 ·3○ ·2	
26	4· ○ 1· 2· ·3	
27	4· 2· .1 ○ 3·	
28	·4 ·2 ○1· 3·	

New Asteroid 1893 AO.—This was discovered by Wolf at Heidelberg, on a photographic plate taken Nov. 6. Its position at $9^h\ 18^m$ Heidelberg M. T. was R. A. $2^h\ 19^m$; Decl. $+ 11°\ 22'$. Daily motion $- 0.6^m$ in R. A. and $- 2'$ in Decl. Magnitude 13.

Elongations of the Satellites of Saturn.

(The western elongations will be found approximately half way between the eastern and other positions may be easily interpolated.)

MIMAS.

		h		
Feb.	3	6.7	A. M.	W
	4	5.3	"	W
	5	3.9	"	W
	6	2.5	"	W
	7	1.1	"	W
	11	6 9	"	E
	12	5.5	"	E
	13	4.1	"	E
	14	2.8	"	E
	15	1.4	"	E
	15	midn.		E
	20	5.7	"	W
	21	4.3	"	W
	22	3.0	"	W
	23	1.6	"	W
	24	12.2	"	W
Mar.	1	4.6	"	E

ENCELADUS.

		h		
Feb.	2	2.4	P. M.	E
	3	11.3	"	E
	5	8.2	A. M	E
	6	5.1	P. M.	E
	8	1.9	A. M.	E
	9	10.8	"	E
	10	7.7	P. M.	E
	12	4.5	A. M.	E
	13	1.5	P. M.	E
	14	10 3	"	E
	16	7.2	A. M.	E
	17	4.1	P. M.	E
	19	1.0	A. M.	E

ENCELADUS Cont.

		h		
Feb.	20	9 9	A. M.	E
	21	6.7	P. M.	E
	23	3.6	A. M.	E
	24	12.5	P. M.	E
	25	9.4	"	E
	27	6.3	A. M.	E
	28	3.1	P. M.	E

TETHYS.

		h		
Feb.	2	4.4	A. M.	E
	4	1.7	"	E
	5	11.0	P. M.	E
	7	8.3	"	E
	9	5.6	"	E
	11	2.9	"	E
	13	12.2	"	E
	15	9.5	A. M.	E
	17	6.8	"	E
	19	4.1	"	E
	21	1.4	"	E
	22	10.7	P. M.	E
	24	8.0	"	E
	26	5.3	"	E
	28	2.6	"	E

DIONE.

		h		
Feb.	1	3.1	P. M.	E
	4	8.8	A. M.	E
	7	2.4	"	E
	9	8.1	P. M.	E
	12	1.8	"	E
	15	7.4	A. M.	E

DIONE Cont.

		h		
Feb.	18	1.1	A. M.	E
	20	6.8	P. M.	E
	23	12.5	"	E
	26	6.1	A. M.	E
	28	11.8	P. M.	E

RHEA.

		h		
Feb.	3	7.7	A. M.	E
	7	8.0	P. M.	E
	12	8.4	A. M.	E
	16	8.8	P. M.	E
	21	9.2	A. M.	E
	25	9.6	P. M.	E

TITAN.

		h		
Feb.	4	6.0	P. M.	S
	8	12.9	"	E
	12	10.5	A. M.	I
	16	2.0	P. M.	W
	20	4 7	"	S
	24	11.2	A. M.	E
	28	9.5	"	I

HYPERION.

		h		
Feb.	2	6.6	P. M.	I
	8	3.2	A. M.	W
	12	12.8	P. M.	S
	17	4.7	"	E
	24	12.9	A. M.	I
Mar.	1	9.2	"	W

IAPETUS.

		h		
Feb.	28	1.0	A. M.	W
Mar.	19	9.9	P. M.	S

Phenomena of Jupiter's Satellites.

Central Time.

		h	m				
Feb.	4	5	06	P. M.	III	Ec.	Re.
		11	30	"	I	Oc.	Dis.
	5	8	41	"	I	Tr.	In.
		10	00	"	I	Sh.	In.
		10	53	"	I	Tr.	Eg.
		11	29	"	II	Tr.	In.
	6	5	58	"	I	Oc.	Dis.
		9	29	"	I	Ec.	Re.
	7	5	22	"	I	Tr.	Eg.
		5	49	"	II	Oc.	Dis.
		6	42	"	I	Sh.	Eg.
		8	13	"	II	Oc.	Re.
		8	31	"	II	Ec.	Dis.
		10	41	"	II	Ec.	Re.
	9	5	49	"	II	Sh.	Eg.
	11	7	25	"	III	Ec.	Dis.
		9	09	"	III	Ec.	Re.
	12	10	36	"	I	Tr.	In.
	13	7	54	"	I	Oc.	Dis.
	14	6	24	"	I	Sh.	In.
		7	18	"	I	Tr.	Eg.
		8	25	"	II	Oc.	Dis.
Feb.	14	8	37	P. M.	I	Sh.	Eg.
		10	49	"	II	Oc.	Re.
		11	07	"	II	Ec.	Dis.
	15	5	54	"	I	Ec.	Re.
	16	5	51	"	II	Tr.	Eg.
		6	05	"	II	Sh.	In.
		8	27	"	II	Sh.	Eg.
	18	5	54	"	III	Oc.	Dis.
		7	59	"	III	Oc.	Re.
	20	9	51	"	I	Oc.	Dis.
	21	7	00	"	I	Tr.	In.
		8	19	"	I	Sh.	In.
		9	14	"	I	Tr.	Eg.
		10	33	"	I	Sh.	Eg.
	22	7	50	"	I	Ec.	Re.
	23	6	07	"	II	Tr.	In.
		8	31	"	II	Tr.	Eg.
		8	43	"	II	Sh.	In.
	25	5	18	"	II	Ec.	Re.
		10	01	"	III	Oc.	Dis.
	28	8	58	"	I	Tr.	In.
		10	15	"	I	Sh.	In.

Approximate Central Standard Times when the Great Red Spot will cross the Central Meridian of Jupiter.

		h m			h m			h m
Feb.	2	1 20 A. M.	Feb.	11	11 39 P. M.	Feb.	21	9 58 P. M.
		9 12 P. M.		12	7 31 "		22	5 50 "
	4	10 51 "		14	1 18 A. M.		23	11 38 "
	5	6 42 "		14	9 10 P. M.		24	7 29 "
	7	12 30 A. M.		16	10 49 "		26	1 16 A. M.
		8 21 P. M.		17	6 40 "			9 08 P. M.
	9	2 09 A. M.		19	2 28 A. M.		28	2 56 A. M.
		10 00 P. M.			8 19 P. M.			10 47 P. M.
	10	5 52 "		21	2 06 A. M.			

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Central Standard Time.]

U CEPHEI.

R. A.....$0^h\ 52^m\ 32^s$
Decl.....$+81°\ 17'$
Period.....$2d\ 11^h\ 50^m$

Feb.	1	9 A. M.
	6	8 "
	11	8 "
	16	8 "
	21	7 "
	26	7 "

ALGOL.

R. A.....$3^h\ 1^m\ 1^s$
Decl.....$+42°\ 32'$
Period.....$2d\ 20^h\ 49^m$

Feb.	11	6 A. M.
	14	2 "
	16	11 P. M.
	19	8 "

R. CANIS MAJORIS.

R. A..... $7^h\ 14^m\ 30^s$
Decl..... .....$-16°\ 11'$
Period..... ..$1d\ 3^h\ 16^m$

Feb.	3	7 P. M.
	4	10 "
	6	2 A. M.
	7	5 "
	11	6 P. M.
	12	9 "
	13	midn.
	15	4 A. M.
	20	8 P. M.
	21	11 "
	23	2 A. M.
	24	6 A. M.
	28	7 P. M.

S CANCRI.

R. A..... $8^h\ 37^m\ 39^s$
Decl.....$+19°\ 26'$
Period.....$9d\ 11^h\ 38^m$

Feb.	6	3 A. M.
	25	2 "

S ANTLIÆ.

R. A..... $9^h\ 27^m\ 30^s$
Decl.....$-28°\ 09'$
Period..... $0d\ 7^h\ 47^m$

Feb.	1	8 P. M.
	2	4 A. M.
	2	7 P. M.
	3	3 A. M.
	3	7 P. M.
	4	2 A. M.
	5	2 "
	6	1 "
	6	midn.
	7	"
	8	11 P. M.
Feb.	9	10 P. M.
	10	10 "
	11	9 "
	12	8 "
	13	8 "
	14	3 A. M.
	14	7 P. M.
	15	3 A. M.
	16	2 "
	17	2 "
	18	1 "
	18	midn.
	19	midn.
	20	11 P. M.
	21	10 "

S. ANTLIÆ CONT.

Feb.	22	10 P. M.
	23	9 "
	24	8 "
	25	8 "
	26	3 A. M.
	26	7 P. M.
	27	3 A. M.
	28	2 "

δ LIBRÆ.

R. A..... ..$14^h\ 55^m\ 06^s$
Decl..... $-8°\ 05'$
Period..... $2d\ 07^h\ 51^m$

Feb.	8	7 A. M.
	15	6 "
	22	6 "

U CORONÆ.

R. A .....$15^h\ 13^m\ 43^s$
Decl..... $+32°\ 03'$
Period..... $3d\ 10^h\ 51^m$

Feb.	7	9 P. M.
	14	7 "
	18	6 A. M.
	25	4 "

U OPHIUCHI.

R. A.....$17^h\ 10^m\ 56^s$
Decl..... $+1°\ 20'$
Period..... $0d\ 20^h\ 08^m$

Feb.	3	6 A. M.
	4	2 "
	8	6 "
	9	3 "
	14	3 "
	19	4 "
	24	5 "
	25	1 "

Variable Star Observers.—I have corresponded lately with the following persons who are observing variables or who wish to take up the work:—

J. D. Devor, 1st Nat'l Bank, Elkhart, Ind.....3-inch refractor.
Geo. M. Brace, High School, Bay City, Mich.....4-inch refractor.
J. C. Sanford, Marblehead, Mass.....4-inch refractor.
Mrs. M. B. Travis, Hampton, N. B.....Field glass.
J. O. Tiffany, Attleboro, Mass.....6-inch refractor.
David Flanery, Memphis, Tenn.....Opera glass.

H. A. PARKHURST.

Comparison Stars for Variables of Long Period.*

T Cassiopeiæ.

Des.	R. A. 1900. h	m	Dec. 1800. °	′	Mag.
a	0	39.6	+ 54	41	6
b	0	21.2	+ 56	5	6
c	0	20.8	+ 56	13	7
d	0	20.6	+ 54	56	7
e	0	18.0	+ 55	15	8
f	0	18.3	+ 54	50	8
g	0	18.9	+ 55	2	8
h	0	20.5	+ 55	10	9
k	0	21.1	+ 55	14	9
l	0	16.1	+ 55	11	10
m	0	19.5	+ 55	10	10
n	0	18.0	+ 55	20	11
o	0	18.3	+ 55	20	12
p	0	17.7	+ 55	11	12
q	0	18.2	+ 55	16	13
r	0	17.7	+ 55	12	13
s	0	17.9	+ 55	13	14
t	0	18.0	+ 55	14	14
u	0	17.7	+ 55	12	14
w	0	17.8	+ 55	13	15
T	0	17.8	+ 55	14	var.

S. Cassiopeiæ.

a	0	41.6	+ 72	8	6
b	1	11.4	+ 77	52	7
c	1	11.2	+ 72	20	7
d	0	44.3	+ 73	1	8
e	1	23.2	+ 72	22	8
f	1	24.5	+ 72	24	8
g	1	7.0	+ 71	58	9
h	0	56.1	+ 72	50	9
k	1	12.7	+ 72	2	10
l	1	13.4	+ 72	4	10
m	1	11.6	+ 72	12	10
n	1	13.8	+ 71	52	11
o	1	12.8	+ 71	50	11
p	1	13.0	+ 71	59	12
q	1	14.4	+ 72	6	12
r	1	12.2	+ 72	0	12
s	1	12.9	+ 72	13	13
t	1	12.2	+ 72	6	13
u	1	11.8	+ 72	5	14
w	1	12.0	+ 72	5	14
x	1	12.9	+ 72	6	15
y	1	125.	+ 72	6	15
S	1	12.3	+ 72	5	var.

S and T Persei.

a	2	15.1	+ 58	43	8
b	2	19.5	+ 58	25	8
c	2	14.6	+ 58	7	8
d	2	9.6	+ 57	45	9
e	2	11.4	+ 58	8	9
f	2	14.0	+ 58	2	9
g	2	14.3	+ 57	58	10
h	2	13.6	+ 58	2	11
k	2	15.9	+ 58	14	11
l	2	15.7	+ 58	9	12
m	2	15.6	+ 58	4	12
n	2	15.6	+ 58	0	12

S and T Persei Cont.

Des.	R. A. 1900. h	m	Dec. 1900. °	′	Mag.
o	2	15.4	+ 58	0	13
p	2	15.8	+ 58	10	14
q	2	15.9	+ 58	6	14
r	2	15.3	+ 58	6	14
s	2	15.6	+ 58	5	15
S	2	15.7	+ 58	8	var.
T	2	12.2	+ 58	29	var.

R Aurigæ.

a	5	6.7	+ 53	6	6
b	5	13.2	+ 54	9	7
c	5	21.8	+ 53	20	7
d	5	8.9	+ 54	4	8
e	5	8.7	+ 53	22	8
f	5	9.5	+ 53	35	9
g	5	9.1	+ 53	29	9
h	5	9.8	+ 53	17	10
k	5	8.4	+ 53	23	10
l	5	9.8	+ 53	24	11
m	5	9.1	+ 53	20	11
n	5	8.3	+ 53	30	11
o	5	8.3	+ 53	19	12
p	5	8.9	+ 53	34	12
q	5	9.0	+ 53	29	13
r	5	9.7	+ 53	29	13
s	5	9.8	+ 53	28	14
t	5	9.5	+ 53	28	14
u	5	9.6	+ 53	28	15
R	5	9.2	+ 53	29	var.

R Lyncis.

a	6	53.1	+ 54	59	7
b	7	3.3	+ 55	47	7
c	6	55.0	+ 54	19	8
d	6	56.9	+ 55	52	8
e	6	51.9	+ 55	53	9
f	6	53.9	+ 55	15	9
g	6	52.0	+ 55	45	10
h	6	54.0	+ 55	10	10
k	6	53.5	+ 55	30	10
l	6	51.6	+ 55	34	11
m	6	52.9	+ 55	32	11
n	6	51.8	+ 55	28	12
o	6	52.3	+ 55	33	12
p	6	52.6	+ 55	30	12
q	6	53.2	+ 55	32	13
r	6	52.7	+ 55	29	14
s	6	52.8	+ 55	30	14
t	6	53.1	+ 55	27	14
u	6	53.3	+ 55	32	15
R	6	53.1	+ 55	28	var.

R Ursæ Majoris.

a	10	34.8	+ 68	57	6
b	10	38.2	+ 67	56	6
c	10	42.1	+ 65	40	6
d	10	56.8	+ 70	35	7
e	10	1.7	+ 69	10	7
f	10	14.5	+ 69	26	7
g	10	27.6	+ 69	13	8

* See Plate accompanying Mr. Parkhurst's article on Variable Stars.

R URSÆ MAJORIS *Cont.*

Des.	R. A. 1900		Dec. 1900.		Mag.
	h	m	°	′	
h	10	35.4	+ 69	8	8
k	10	48.5	+ 68	28	9
l	10	49.6	+ 69	6	9
m	10	27.7	+ 68	54	9
n	10	35.5	+ 69	4	9
o	10	38.1	+ 68	48	10
p	10	40.5	+ 69	9	10
q	10	40.5	+ 69	22	11
r	10	37.7	+ 69	21	11
s	10	37.0	+ 69	17	12
t	10	37.6	+ 69	15	12
u	10	36.7	+ 69	15	12
w	10	38.8	+ 69	18	13
x	10	38.2	+ 69	20	14
y	10	37.0	+ 69	19	14
z	10	37.9	+ 69	16	14
α	10	38.1	+ 69	19	15
R	10	37.6	+ 69	18	var.

T URSÆ MAJORIS.

a	12	25.4	+ 59	19	6
b	12	35.1	+ 61	26	7
c	12	34.5	+ 61	34	7
d	12	44.2	+ 61	22	8
e	12	35.9	+ 60	5	8
f	12	34.7	+ 60	18	8
g	12	32.8	+ 59	46	9
h	12	29.6	+ 60	17	9
k	12	34.0	+ 60	15	9
l	12	33.9	+ 60	10	10
m	12	34.3	+ 60	4	10
n	12	33.4	+ 59	52	10
o	12	33.9	+ 59	52	11

T URSÆ MAJORIS *Cont.*

Des.	R. A. 1900.		Dec. 1900.		Mag.
	h	m	°		
p	12	34.8	+ 60	8	12
q	12	31.3	+ 60	4	12
r	12	32.8	+ 59	58	12
s	12	34.2	+ 59	59	13
t	12	32.1	+ 60	0	14
u	12	33.1	+ 59	59	14
w	12	32.2	+ 60	1	14
x	12	32.5	+ 60	2	15
y	12	31.9	+ 59	59	15
T	12	31.9	+ 60	2	var.

S URSÆ MAJORIS.

a	12	38.7	+ 61	42	6
b	12	35.1	+ 61	26	7
c	12	34.5	+ 61	34	7
d	12	44.2	+ 61	22	8
e	12	35.9	+ 60	5	8
f	12	36.4	+ 61	22	9
g	12	37.7	+ 61	25	9
h	12	33.8	+ 61	12	10
k	12	40.2	+ 61	15	10
l	12	41.7	+ 61	40	10
m	12	40.6	+ 61	33	11
n	12	40.6	+ 61	44	12
o	12	41.2	+ 61	33	12
p	12	41.7	+ 61	32	12
q	12	41.4	+ 61	36	13
r	12	37.5	+ 61	36	13
s	12	40.2	+ 61	39	14
t	12	40.4	+ 61	41	14
u	12	40.2	+ 61	41	14
w	12	40.1	+ 61	40	15
S	12	39.6	+ 61	38	var.

PRACTICAL SUGGESTIONS.

Persons interested are requested to remember this corner and to write briefly and frequently for it.

10. In the answer to S. G. S. in December issue it is stated "that a central 2-inch area of a high class objective should do better work than the whole of a 3-inch high class objective is utterly impossible. The only thing that it would indicate is that there is something wrong with the 3-inch objective."

This is explicit and satisfactory so far as it goes, but does not exhaust the query as the present writer interprets it and would be pleased to see it answered.

The following does better, but scarcely reaches the core, except possibly by implication. "Diaphragms will not improve a first class objective."

The point is this: Does the peripheral portion of the spherical surfaces of a high class objective do as good work as an equal area of the central portion of the same glass? W. B. H.

11. Would an objective be rated first class if by using diaphragms—first an annular, then a central one—it is ascertained that the central portion of the glass, amounting to less than a third of the entire area, does better work than the remaining portion—the peripheral—constituting more than two thirds the area of the whole spherical surface? W. B. H.

12. Inasmuch as celestial photography discloses the existence of myriads of stars too minute to be seen with the aid of the largest telescope, why is it that a 3½-inch refractor in the possession of the writer, gives a better or more distinct view of lunar scenery—craters in particular—than the best photographs, assuming as a fair sample the one taken at the Goodsell Observatory, and found in the frontispiece of POPULAR ASTRONOMY for September? W. B. H.

Answer. The great difference in the brightness of the features of the lunar surface makes it difficult, if not quite impossible, to bring out on the same negative, all the minute details that can be seen in a small telescope. If the exposure is timed for the mountains and bright table lands and streaks, then the details of the seas and valleys will be lost. If the exposure is made longer so as to get details in the darker portions, then the brighter parts will be over exposed and appear on the plate as simple patches of confused light. It is a difficult task to divide the time rightly between these extremes of light and shade and get the best results for both. If the photographer had either phase alone to deal with, he would quickly show us astonishing results in lunar photography as has already been done repeatedly in stellar exposures.

When the different parts of a landscape, for example, are so related that the brighter parts may be covered during a part of the time that the darker ones are exposed, the details of all parts of the view may sometimes be well secured in this way. It would be difficult to apply such a method to the Moon. The best results at Goodsell Observatory in photographing the moon were secured Dec. 22, 1893, when it was within a few minutes of the full and was passing the meridian and was also within nearly 15° of the zenith. The image was about $3^{3}/_{4}$ inches in diameter and the exposure was one-half second. The picture is an excellent one and will soon be reproduced for these pages.

12. An interested reader of these suggestions says, the answer by J. A. B. to query No. 5 was a revelation to him, and that he was glad to learn that solid eyepieces give nearly one "third more light" than the Huygenian ones do. He further adds that he is tempted to order two or three at once if they are not too expensive. Possibly J. A. B. will give the price of this kind of eyepiece.

GENERAL NOTES.

The publication will hereafter be issued before the first day of the month for which it is dated.

So many subscribers kindly responded to our request last month for the names of persons interested in astronomy that the request is continued. See first page of advertisements.

Optical Glass.—Mr. J. A. Brashear's series of articles on optical glass begins in this number. In our next he will present a number of illustrations showing how the great 40-inch disc belonging to the Yerkes telescope of the University of Chicago, was worked from the original lump of glass. The nine photographs were presented to Mr. Brashear by Mantois of Paris. They will make one of the most interesting plates yet published.

Variable Stars of Long Period.—The neat lithographic plate of variable stars of long period accompanying Mr. Parkhurst's article is furnished by kindness of Professor E. C. Pickering of Harvard College Observatory. Another like it will soon follow.

Professor Proctor's Monument.—Miss Mary A. Proctor, daughter of Professor Richard A. Proctor has recently furnished us with data for a sketch of his useful and very busy life. Beautiful plates will accompany the brief article.

Contributors will please bear in mind to make articles brief for space every month seems to be in good demand. From three to five printed pages is a fair average length for ordinary articles. The great variety desired for every issue is the reason for this request.

Visualizing the Earth's Motion.—In the December issue of POPULAR ASTRONOMY, Eliza A. Bowen shows how the Earth's *revolution* may be made manifest to the eye. The following is a simple method of rendering its *rotation*, also visible: Place on the floor of a room free from tremors and air currents, a good sized bowl nearly filled with water and sprinkle over the surface of the water an even coating of lycopodium powder, and across this make a narrow black line of pulverized charcoal. Place the bowl so that the black line shall coincide with a crack in the floor, or, if the room be carpeted, lay a stick upon the floor exactly parallel with the mark. After a few hours it will be found that the line is no longer parallel with the stationary object, but has moved from east to west proving that, during this interval, the Earth has moved from west to east.

The reason appears to me to be that the solid floor has with the Earth and bowl moved from west to east, and so has the water, also, but at a slower rate, as there is a slight inertia, of which the yielding liquid does not instantly partake, to be overcome. It will be seen that the line or charcoal mark always moved from east to west. L. SWIFT.

Naked-Eye Observations of Jupiter.—When the Opposition of Jupiter has passed there remains much interesting work for the naked-eye observer in watching the proper motions of the planet so long as it is visible.

But he should be warned in regard to the apparent motion of the planet (I.) This is the daily apparent movement from the eastern to the western horizon, causing the planet to rise daily above the eastern horizon and to set behind the western, as do the Sun, Moon and stars. This apparent movement is due to the Earth's rotation upon its axis. (II.) This is the apparent motion from the eastern to the western horizon, detected by watching the planet for some weeks at the same hour of the night, thus throwing out the effect of the Earth's daily motion. This apparent motion is due to the Earth's revolution round the Sun. The fixed stars have the same apparent movement, except that Jupiter's real motion retards a little the apparent movement due to the Earth's revolution. All these movements to and from the horizon are to be disregarded.

The planet's real or proper motion, which is the chief object of attention is indicated by its change of place among the fixed stars. Whenever it crosses a line joining two other stars on the same or opposite sides of it, its motion becomes evident at once by the making or breaking of the line. It often forms with other stars, regular figures, triangles, diamonds, etc , and any variation in the regularity of the figure makes the movement quickly evident.

(III.) But the inexperienced observer will be surprised to find that Jupiter is now moving apparently west, not east. This is apparent, and lasts for sixty days before and sixty days after opposition, when the planet seems to become stationary for about two weeks, after which we can plainly see that it is moving eastward. This is an apparent movement precisely similar to that which takes place when a faster walker overtakes and passes a slower walker bound in the same direction as himself. It takes place near opposition only, because only then, the Earth and planet move towards the same quarter of the heavens. Their direction of revolution is always the same. E. A. B.

Errata in December number—
Page 165, line 15 from top, for β Cassiopeiæ, read B Cassiopeiæ.
Page 167, line 10 from bottom, for Nov. 1, read Nov. 16.